NASA SP-29

PROCEEDINGS OF THE SECOND

NASA-INDUSTRY PROGRAM PLANS CONFERENCE

WASHINGTON, D. C. • FEBRUARY 11-12, 1963

Office of Scientific and Technical Information
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Washington, D. C.

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Washington 25, D.C. - Price $1.25

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WELCOME AND OPENING REMARKS

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NASA depends heavily upon American industry as a partner in carrying out this country's space program. More than 90 percent of the money appropriated to NASA by Congress is currently being spent through American private industry.

The First NASA-Industry Program Plans Conference held July 28–29, 1960, provided industrial management an overall picture of the NASA organization and program, and established an adequate basis for subsequent conferences held at Goddard Space Flight Center, Marshall Space Flight Center, and Jet Propulsion Laboratory. At these 1960 Center Conferences the scientific and technical content of NASA's program plans were further developed in sufficient detail to be of direct utility to scientists and engineers concerned with program and project proposal formulation in organizations whose capabilities and interests overlap NASA's current and future requirements.

NASA's organization has grown and changed so much since July 1960 and our program and budget have so expanded that there has been a growing demand by industry for NASA to repeat the program plans conferences at Headquarters and at the Centers.

Industry has asked that we let them know more accurately what we are now planning for the future so that they can more intelligently invest in their own facilities, their own research and development programs, and develop their organization to make better-informed responses to our future requests for proposals.

The purpose of papers 2 to 34 is to acquaint industry with the thinking about NASA projects already underway, and to discuss the studies, which have been approved, of possible new projects. Hopefully, these discussions will bring to bear upon our programs the full force of the creative and inventive capabilities which exist in American business organizations. At the same time these papers should be of benefit to industry in helping to develop research and development programs more efficiently.

1 Keynote Address

JAMES E. WEBB
Administrator

The presence of so many representatives of American industry at this Second NASA-Industry Conference is a source of great encouragement to all of us in the National Aeronautics and Space Administration.

Speaking recently in New York, the distinguished and able Chairman of the House Committee on Astronautics, the Honorable George P. Miller, of California, expressed some views on the role of industry in the NASA program which are quoted as follows:

> The American people are convinced that we must explore space. And they expressed clearly and firmly this conviction through their elected representatives.
>
> Thus the people look to Congress and to NASA for the assurance that our national space program, especially the manned lunar landing, will be conducted with the utmost vigor possible. And in turn, *Congress and NASA look to private industry in order to achieve in practical terms all of our objectives.*

Congressman Miller expressed a point-of-view which all of us in NASA share. The effort in which we are engaged, although financed and managed by the Federal Government, is dependent for success on the efforts of many American industries, large and small, throughout the 50 States. The achievement of the U.S. objective stated by President Kennedy—preeminence in space and the utilization of the skills and knowledge gained for the benefit of all our citizens and those of other nations—is a truly national undertaking which will demand the best of all of us.

The policies and programs involved in this undertaking will be described in the papers which follow. Dr. Hugh L. Dryden, the Deputy Administrator of NASA who has served with this agency and its predecessor NACA through a long and distinguished career, will outline "NASA Missions and Future Trends."

D. D. Wyatt, Director of the Office of Programs, will outline the NASA budget which the President has proposed for fiscal year 1964. Albert F. Siepert, Director of the Office of Administration, will describe the NASA organization.

Since fiscal year 1959, NASA's first year, its budget has grown from $339 million to $3.7 billion in the current fiscal year. The President has recommended an appropriation of $5,712 million for fiscal year 1964. It is probably true that never in our peacetime history has an agency of the Government grown so rapidly.

Of the $5.7 billion requested by the President for fiscal year 1964 about two-thirds, or $3.7 billion, will be expended in the area of manned space flight, and is related directly or indirectly to realizing one of our major initial goals in space—manned exploration of the moon within this decade.

Why, some ask, the moon? The answer is that valuable scientific information relating to a clearer understanding of the universe can be gained, and success in achieving this goal requires essentially the same progress in science and technology which will be required to achieve our broader objective—that of becoming the world's leading spacefaring nation. Our reasons for exploring the moon are, for the most part, identical with those which prompted us to undertake an accelerated space program in the first place.

These reasons, stated in more detail, include:

(1) *Vital scientific knowledge can be gained.* Exploration of the moon is important because

its surface has preserved the record of its history for a much longer period than the earth, and promises to yield information dating billions of years into the past.

(2) *Continued superiority in science and technology is essential to our leadership of the Free World, and our prestige among the uncommitted nations.* Exploration of the moon requires the kind of overall much expanded competence in space which we can develop on a timetable competitive with the capacity of the U.S.S.R. to do the same.

(3) *Our national security demands that we act to insure that no hostile power will use space as an unchallenged avenue of aggression against us.* The scientific knowledge and technological skill developed in our program of lunar exploration will give us that assurance, and will form the basis for any military applications which the national interest may require.

(4) *Practical applications of space technology will expedite our economic growth in such areas as more efficient utilization of energy, advanced electronics, and new materials.*

In summary, the capability we are developing to travel to the moon, learn its secrets, and return safely is a focal point for our national efforts to achieve mastery of space. A noted space scientist, Dr. James A. Van Allen, of the State University of Iowa, put it very well when he said:

> This matter of manned lunar exploration is an undertaking of truly heroic proportions. It provides a graphic test of our national technical capabilities, and our national fortitude and integrity. I, for one, would be most distressed to see the United States shrink from this challenge.

To achieve mastery of space requires that we add substantially to our scientific knowledge and to our utilization of technology. The NASA program is moving forward on both of these fronts. In a complex effort such as this, conducted in the new medium about which much is yet unknown, the scientist and the engineer work closely together and grow increasingly dependent upon one another.

In the exploration of space, the scientist must depend upon the enginer to design the equipment which will enable him to investigate conditions and forces which exist there. But at the same time, the enginer must look to the scientist for precise knowledge which will enable him to design equipment which will operate, or sustain human life, in this harsh and unfamiliar environment.

The NASA program, therefore, must expand both science and technology. We must move forward on a broad front. We cannot afford to be trapped into a narrow program—one limited, for example, to developing only the technology needed to reach the moon with state-of-the-art hardware. To do so might well be to find, some years hence, that we had won the battle and lost the war as far as ultimate and enduring superiority in space is concerned.

In the National Aeronautics and Space Administration, basic in all our decisions is the concept that we will encourage wide-spread participation in the space program by American industry, to develop a broad base of competence in space technology by contracting out to industry the maximum possible amount of our work and utilizing the competitive forces of the marketplace to obtain top-notch performance. More than 90 percent of our work is now performed under contract with industry, universities, and private research organizations.

Some examples of the steps taken to assure competition and broad opportunities for participation in space work by industries of every size throughout the nation are cited as follows.

First, we have taken steps to try to make certain that contracting patterns will not become frozen, that major areas of competence will not be preempted or locked in by single sources. Typical of our actions under this policy was the establishment, for the assembly and testing of our new multimillion-pound-thrust boosters, of the Michoud Plant at New Orleans, and the nearby Mississippi Test Facility, as Government installations, with resources available to private contractors selected through competition.

This decision, that the assembly and testing of our largest boosters would be carried on in centrally located Government facilities, was made with the deliberate intention, among others, of keeping open a continuous competition within industry for the contracts to build future stages.

Second, in the area of manned space flight we have developed through the Bellcom Corp., a systems engineering group organized by the American Telephone & Telegraph Co., a capacity to examine continuously the developing state of the art in the areas essential to our success, to match continuously the results against the concepts and assumptions underlying our programs, and to relate this matching to the hardware and mission profiles toward which we are working. Through a contract with the General Electric Co., we are endeavoring to provide a means for measuring and storing in computers performance and test data on the vital components and the finally assembled boosters and spacecraft in an effort to increase reliability substantially. These arrangements will not be used to provide crutches for NASA contractors, but rather to measure and insure competence on the part of the contractor himself.

It might be added that we have resisted every impulse to establish these groups as nonprofit corporations.

The contracts insure that the full responsibility of the corporations, both AT&T and GE, are pledged to the success of these extremely important and difficult endeavors.

Third, as a policy in making prime contract awards, we are steadily moving in the direction of insisting that prime contractors obtain components from those sources which have already developed reliable hardware. Our object here is not only to insure that NASA obtains the best available performance, but to encourage prime contractors to seek out superior subcontract skills among companies of proven performance, rather than risk failure or increased costs by trying to develop internal or new sources of competence to perform these tasks.

This policy is of great significance to all segments of industry and areas of the Nation because it means that specialized or smaller firms can afford to invest time, effort, and money in perfecting a product with the assurance that the prime contractor must listen to their evidence showing what its performance is. The prime contractor cannot reject available outside skills simply to keep the business within his own organization or pattern of supplies.

In short, we are making a deliberate effort to use the self-policing forces of the marketplace to avoid building Government competition with industry, and also to maintain sufficient managerial and technical capability in our own organization to make certain that our contractors are giving us the reliability we must have and the taxpayer a dollar's worth of work for every dollar we spend.

As a part of this latter effort, we are looking to multidisciplinary centers of competence in the universities, and to civil service research and development centers such as the new Electronics Research Center which we propose to establish in the Boston area. This center is not intended to compete with industry, but to give us the capability to manage a vast program in electronics similar to that which NACA developed in aeronautics.

Another basic policy which we are following in the award of research contracts, particularly those which are concerned with basic research, is to do what we can to assist the universities of the Nation in the training of additional scientists and engineers, particularly those who are working toward advanced degrees.

As a nation we must look to the future requirements for highly trained scientific and engineering manpower. Much of the research work which NASA required is the kind of work in which graduate students can participate under the direction of, and with the inspiration of, a qualified scholar or researcher.

Thus NASA can help make the university a center for developing men with eager, trained, self-starting minds and also a center of creative activity in basic research in support of broad national objectives.

In addition to the placing of specific research contracts with universities, NASA is taking other steps to help strengthen the universities and assure a continuing supply of scientific and technical manpower. These include the encouragement of interdisciplinary groups within the university for research in broad areas, to be supported by contracts or grants; support of predoctoral training in the fields of space science and technology and, in some instances, the financing of research facilities needed for expansion.

Of interest to American industry, and of great future value to our national economy, is one of the provisions we attach to grants for facilities.

Since one of the responsibilities imposed upon the space agency in the space act is that of endeavoring to make the results of space research available for wide application, for some time we have been exploring means by which industry can identify useful innovations resulting from our research. Several pilot studies have been made, and these suggest that the answer may lie in the development of closer relationships between university-based scientists and engineers on the one hand, and those in the industrial community on the other.

To test this, and at the same time to stimulate in several regions the industrial application of the knowledge being gained in space research, we are incorporating in our university facilities grants, provisions which say essentially this:

"The university will undertake, in an energetic and organized manner, to create a broadly based multidisciplinary team to explore mechanisms whereby the progress and research results achieved in space science and technology may be fed into the industries and segments of the economy with which the university normally has close relations."

In addition, it is specified that "research is to be encouraged on ways and means to expand and search for practical applications and in the economic and social impact of our national involvement in space exploration. Furthermore, the university will undertake to make the scientific community, as well as the industrial and business communities, aware of new opportunities for application of specific developments or processes stemming from the space program."

In conclusion, the importance of the work which those already in the program are doing should be emphasized.

Our objective in NASA is to build competence in space for the United States, and to be, in the words of President Kennedy, "in a position second to none."

As is well known and as the President continues to emphasize, we have been behind in space, and in the area of manned space flight—largely because of the early Soviet lead in producing large, reliable boosters. We are still behind. During the past 5 years we have made substantial progress in overcoming this lead, and our Saturn and Advanced Saturn vehicle development programs give promise, in the not distant future, that we will also excel in big booster capability. That, at least, is our goal, and barring some development which is now unforeseen, we should achieve it.

In the programs of the National Aeronautics and Space Administration we seek a national competence in space which may be applied for any purpose which the national interest may require. NASA, like its predecessor NACA, is a research and development organization. It is our job to provide the basic scientific knowledge and technological skill which will enable other agencies of the Government to carry out the operational responsibilities which are theirs.

Thus, we work in close cooperation and collaboration not only with the Department of Defense, but with many other agencies such as the Weather Bureau, the Communications Satellite Corp., and the Atomic Energy Commission, in order that what we do will meet their needs.

It is important that each of us, as we consider the contribution which we can make to this effort, keep constantly before us the importance and urgency of our responsibilities.

We must remember that our national security itself is heavily involved in the space competition. Not only our prestige but our capacity for constructive international leadership and our economic and military capacity for technological improvement depend upon a superiority in science and technology that is understood and accepted.

The nations of the world, seeking a basis for their own survival, continuously pass judgment upon our ability as a nation to make decisions, to concentrate effort, to manage vast and complex technological programs in our own and, not infrequently, in their interest. It is not too much to say that in many ways the viability of representative government and of the free enterprise system in a period of revolutionary changes based upon science and technology is being tested in our space programs.

2 NASA Missions and Future Trends

HUGH L. DRYDEN
Deputy Administrator

The NASA missions derive from the national objectives stated in Section 102–c of the National Aeronautics and Space Act of 1958. These objectives, somewhat abbreviated, are as follows:

(1) Expansion of human knowledge of phenomena in the atmosphere and space.
(2) Improvement of the usefulness, performance, speed, safety, and efficiency of aeronautical and space vehicles.
(3) Development and operation of vehicles capable of carrying instruments, equipment, supplies, and living organisms through space.
(4) Establishment of long-range studies of the potential benefits to be gained from the utilization of space activities for peaceful and scientific purposes.
(5) Preservation of the role of the United States as a leader in aeronautical and space science and technology and in the application thereof to peaceful activities.
(6) Making available to agencies concerned with national defense of discoveries that have military value or significance and the corresponding exchange from defense agencies to NASA.
(7) Cooperation by the United States with other nations and groups of nations in space activities.
(8) The most effective utilization of the scientific and engineering resources of the United States.

To realize these objectives NASA has engaged in the conduct of a broad program which, for convenience, we divide into four parts: manned space flight, space science, applications, and advanced research and technology.

The specific objectives of the manned space flight program are: to explore the problems connected with the travel of man in space, at first in orbital flight about the earth for short periods, later in flights to the moon, and still later to the planets; to construct the launch vehicles and space hardware necessary to realize these missions; and to use the hardware for the manned exploration of space, including scientific measurements made possible by the presence of man in space and the application of manned space flight for other useful purposes.

The specific objectives of the space science program are to obtain scientific data on the space environment, the sun, earth, and planets, and the galaxy, using unmanned spacecraft equipped with instrumentation and telemetry to relay data to the ground. The scientific data are of great value for man's understanding of the physical universe and are essential to the design of all space vehicles, including manned spacecraft.

The ojectives of the applications program are to discover and realize useful applications of earth satellites and other spacecraft in addition to their uses for scientific research. At present our primary interests are in applications of earth satellites to meteorological research and weather forecasting, to long-distance wide-band radio communication, and navigation.

The specific objectives of the program in advanced research and technology are: to understand fundamental phenomena underlying aeronautical and space technology; systematic testing to obtain design data for aeronautical and space vehicles for the future; and experimentation on advanced components and subsystems to facilitate rapid development of future systems in the shortest possible time and at minimum cost. Imaginative projects in this field provide substantial insurance against technical surprises in the ongoing engineering development of launch vehicles and spacecraft, which must proceed somewhat in advance of complete understanding of all the phenomena involved.

The following discussion concerns some of the present missions and future trends in each of these program areas. For manned space flight, the one-day earth-orbit mission completes the Mercury project. Major Gordon Cooper has been selected as the astronaut for this mission scheduled for April 1963 with Commander Alan Shepard as his backup. If for any reason the objectives are not fulfilled to our satisfaction a backup capsule and launch vehicle are available.

Project Gemini will provide information essential to Project Apollo on man's performance in long-duration flight, and in the technique of rendezvous as well as provide operational experience for the many persons involved in the execution of a long-duration mission. As recently announced, NASA and DOD will join in programing Gemini flights to insure effective use of Gemini for NASA and DOD needs. The project is managed by NASA. In the Apollo project which is in the group of projects carrying the highest national priority, the technology and hardware will be developed within this decade to land men on the moon and to return them safely. These are the presently approved projects the accomplishment of which will take us several years into the future.

What comes next in manned space flight? Not just NASA, but many persons and agencies will be involved in obtaining the answer. Major NASA programs of the future will, as in the past, be determined within the total context of national need and of the availability of resources. I wish to emphasize this point. To indicate a possibility, or to undertake a study of a new direction, is just that and no more. The Nation's interest in space, and the level of support, will in the long run be determined by the large policy decisions of the American Government.

We do have the responsibility of looking ahead—of being ready to indicate next steps, or alternate next steps, to the President and the Congress, and of making our own recommendations as to a course of action. To satisfy this responsibility we make many studies, both of our own and by industry groups under contract. The approved study program will be outlined in subsequent papers. Perhaps only a few of the studies will be along lines which eventually lead to hardware development. In the manned space flight area, the obvious candidates for additional or follow-on projects are more extended exploration of the moon by the establishment of a station on the moon permitting prolonged occupancy, a manned laboratory orbiting the earth as a satellite, and manned reconnaissance of the planets. Each of these involves a companion project in the launch vehicle field, a lunar logistic vehicle, a resupply vehicle to the orbiting laboratory which might be Gemini or Apollo or a new vehicle, and the Nova which might be either a liquid or solid rocket or perhaps Saturn V plus a nuclear stage.

It seems to us that an orbiting laboratory is a necessary preliminary to manned planetary expeditions, since both man and equipment must be tested for months in the space environment, since information must be obtained as to whether artificial gravity is necessary in the manned spacecraft for planetary travel, and since experimental demonstration must be made of assured reliability for the period of the journey. In the case of manned flight to the moon the Apollo vehicle is itself the space laboratory in which men and equipment can be qualified for the necessary period by orbital flights about the earth, and in which limited scientific and technical investigations not directly related to the manned lunar mission can be conducted.

We believe, therefore, that manned planetary exploration comes in a later time period after a suitable manned orbiting laboratory is available. The concepts of orbiting laboratories range from the Mercury, Gemini, and Apollo capsules as one-, two-, and three-man orbiting laboratories, respectively, to very large space stations, rotating to provide artificial gravity. Obviously the capsules presently in the program do not have sufficient space available for experimentation, and have only a limited lifetime in orbit. Something larger, of longer duration in orbit, and with resupply capability is required. Many exploratory design studies have been made of the technological feasibility of assembling a large space laboratory in space from multiple launches with one or another of the available launch vehicles. We believe, however, that technical feasibility alone does not justify a project of this magnitude and cost. We are attempting to grasp the problem from the other end, that is to ask what one can and would do in a space laboratory in specific fields of science and technology with a view to establishing a realistic and useful concept. We hope that such studies will provide the information necessary to justify and support a decision to be made perhaps a year from now. The program must be designed to fulfill national needs.

As previously stated the orbiting laboratory will require a resupply vehicle, but it is possible that this need can be met by the Gemini or Apollo capsule. Depending on the time scale, the resupply vehicle might be derived from the X-20, or Dyna-Soar, technology, if it turns out that extensive maneuvering is required during reentry.

This brings us to the lunar station and its companion lunar logistic vehicle. Here, also, the concepts of a lunar station vary from a temporary shelter to extend the residence time of the Apollo astronauts on the moon for a few days to a large more or less permanent base. Likewise, the concept of a lunar logistics vehicle varies from the rather simple substitution of a freight carrying spacecraft for the lunar excursion module on the Apollo launch vehicle (which in this instance will carry men in the command module who return to earth without landing) to a large unmanned spacecraft carried to the moon by the Saturn V launch vehicle or by some new launch vehicle of still greater capacity. Obviously, a commitment to the more ambitious concept of a lunar logistic vehicle is in fact a commitment to proceed with a large lunar station and extended exploration of the moon. Although technologically this project could probably move very rapidly, we again need to study whether there is some justification in addition to the purely scientific exploration of the moon. We will be aided in assessing the situation by the early measurements and observations from Ranger and Surveyor. Studies of the various concepts have been underway for some time.

We invite any information which is thought to be useful in charting the course of space exploration beyond the manned lunar landing. Those of us who carry the responsibility for recommendation or action will of necessity by the fall of 1963 make a decision whether to begin preliminary steps toward hardware development on one or more of these projects.

The detailed presentations of the approved projects within the present space sciences program are given in subsequent papers. In general, 1963 will see the first flight of the Orbiting Geophysical Observatory and the 1964 budget includes funds for the continuing development of the Orbiting Astronomical Observatory, for a fly-by of Mars at the next opportunity, and for projects for interplanetary and ionosphere monitor satellites.

Looking to the future we foresee a certain merging of parts of the space science program with the manned space flight program, as we study the types of scientific programs that might be carried out by men in Gemini and Apollo. In similar fashion we are studying the types of scientific measurements which might be made in manned laboratories in space. There is some thinking about the launching of an artificial comet, but this spacecraft, if approved, may not be as interesting as might be supposed. It has no electronics, no stabilization, in fact nothing on board. It consists of a block of some substance which will evaporate in space to form a tail and the whole thing would be observed through telescopes optically.

While the Atlas-Agena and the Atlas-Centaur will suffice for much of the planetary program, some thought is being given to the kinds of experiments which might require the use of Saturn for the unmanned exploration of the planets. Such a launch vehicle would be required for orbital and landing missions to Mars and Venus. However, it seems likely that such flights, if approved, would come at the end of the decade.

In the biosciences area the 1964 budget provides funds for a flight program involving small biosatellites with a life of about 14 to 30 days. The spacecraft will utilize the recovery technology developed by the Air Force. One of the objectives of this program is to determine the effect of the space environment on both cellular and complex living organisms. Another objective of the bioscience program is the determination of the existence or nonexistence of life on nearby celestial objects. Several instrumentation developments are underway, so-called life detectors, probably to be flown first on Surveyor to the moon and later hopefully to a landing on Mars. Some indirect information will certainly be obtained as a result of the Mars fly-by.

The currently approved programs in the applications area are Tiros and Nimbus meteorological satellites, and Relay and Syncom communications satellites. Two additional Relay launchings are on the program and studies are being made of an Advanced Syncom. The most difficult technical problems in the satellite aspects of the communications satellite system are those of synchronous satellites and it may be expected that NASA will do considerable research on the stabilization, attitude and position control, and related technical aspects. Other problems in any of the communications satellites are securing a longer lifetime and multiple launch of payloads from a single launch vehicle.

By law NASA is available to perform certain services as well as research and development for the new Space Communications Corp., but specific plans will have to await the completion of the organization of the corporation and the development of its own plans. NASA's program must remain flexible and responsive to the needs of a rapidly changing situation.

The 1964 budget provides for a vigorous program of advanced research and technology in the many fields which support aeronautics and space development and operations. For budgetary purposes we group the many activities under space vehicle systems, electronic systems, human factors systems, nuclear electric systems, nuclear rockets, chemical propulsion, space power, and aeronautics. The program will be presented in a subsequent paper and only brief comments are made here. First, there is emphasis on the imaginative use of ground facilities for investigating phenomena of interest, for simulation of the space environment, and for the simulation of flight operations with man in the loop. Ground tests are supplemented by carefully selected flight tests, for critical checks, or to attain conditions which cannot yet be satisfactorily simulated on the ground. An example of such a flight test is Project Fire, to investigate the heating environment and heating effects around a blunt vehicle having a shape similar to Apollo during an actual reentry flight at 37,000 feet per second, using the Atlas booster plus an Antares solid rocket. A later flight will extend the data from the lunar return velocity of 37,000 feet per second to the interplanetary return velocity of 45,000 feet per second. Such flight tests provide critical checks for improving confidence in the results obtained in ground facilities and from theory. Another area where flight tests are required is that of the effect of zero gravity which cannot be simulated on the ground. Thus, flight tests are required for studying the problems of liquid fuel handling and storage during unpowered space flight with special attention to cryogenic fluids and the influence of heat transfer. Another area requiring flight research is the study of radiation of various wavelengths near the horizon needed as a guide in the development of horizon scanners for use in guidance systems.

Included in the advanced research and technology program is the work on electric propulsion, including both the nuclear electric power supply and the various types of electric thrusters, the development of nuclear auxiliary power units such as Snap 8, and the development of nuclear rockets. The work on nuclear devices has been carried out in cooperation with the Atomic Energy Commission.

The future trends in this program will be affected very much by the experience actually gained in space flight and the decisions that will be reached on the manned space flight programs beyond Apollo. The program at any given moment must include work on the more immediate problems for which better solutions are required, work on problems that are foreseen in projects to be undertaken in the future, and the exploitation of new ideas to determine their practicability through system and component development and test. Such a well-rounded program in advanced research and technology will be insurance against technological surprise, offering alternative paths to the solution of key problems, and will provide the basis for accelerated engineering development of flight hardware, when needed.

In planning for the future it has been our custom to set for ourselves certain mission objectives or target milestones for the years immediately ahead. For calendar year 1962 these objectives were the orbital flight of an astronaut, the launching of an orbiting solar observatory, the impact landing of instruments on the moon in Project Ranger, the launching of a Topside Ionospheric Sounding satellite, the launching of a Venus probe, and the launching of a realtime active communication satellite leading to civil application. All but one of these targets were accomplished. The three-orbit flights of Glenn and Carpenter and the six-orbit flight of Schirra are well known as are Telstar, Mariner, Alouette, and OSO. Our Ranger flights were unsuccessful in 1962 but we look forward to success in 1963.

One of the most important targets in 1963 is the launching of a two-stage Saturn I, realizing and demonstrating the weight-carrying ability of 20,000 pounds which we set out to obtain at the very beginning of NASA. Other important targets for 1963 are the launching of the Nimbus meteorological satellite and the Orbiting Geophysical Observatory.

In 1964, the targets are the qualification of the 200,000-pound-thrust J–2 hydrogen-oxygen rocket engine for flight, the qualification of the 1½-million-pound-thrust F–1 rocket engine for flight, the soft landing of instruments on the moon in Project Surveyor, the reconnaissance of Mars by an unmanned vehicle, and the launching of the Apollo capsule in earth orbit, the demonstration of rendezvous between a two-manned satellite and an unmanned satellite in Project Gemini.

In 1965 we hope to launch the first Orbiting Astronomical Observatory and to make the first launch of the Saturn V first stage which employs five F–1 engines for a total thrust of 7½ million pounds. In the last half of the decade we expect to flight-test the Snap system and the nuclear thermal engine Nerva in the Rift spacecraft stage, and prior to 1970 we expect to accomplish the Apollo mission for landing man on the moon and returning him safely to earth.

Three programs deserve special mention: aeronautics, our international program, and our sustaining university program. In aeronautics, the X–15 research airplane program, conducted in cooperation with the Department of Defense, continues to provide data on manned maneuverable flight and to carry out special research investigations at high speed and altitude. The present and future aeronautics program contains investigations in the areas of V/STOL aircraft, supersonic transports, and hypersonic vehicles. Work on V/STOL vehicles has entered the operational prototype stage. Activities in connection with the commercial supersonic transport have been conducted in cooperation with the Federal Aviation Agency. In this field, aeronautical research has been directed toward the development of a configuration which has extended range performance at supersonic speeds while retaining useful subsonic takeoff and landing characteristics. Air-breathing propulsion research is concentrated in the supersonic and hypersonic regime. The aerodynamic and propulsion work in the hypersonic area is closely coordinated with the research efforts of the U.S. Air Force leading ultimately to the assessment of the feasibility of hypersonic aircraft for military and civil use. This work may eventually lead to a cooperative hypersonic research airplane as a successor to the X–15.

Our international programs are conducted as a part of the regular activities of the program directors, one criterion for the selection of projects being that they contribute to the objectives of the National Aeronautics and Space Act of 1958. This program has grown considerably so that there are now some 61 political jurisdictions which have joined NASA in flight support or training programs. During 1962 the first international satellites, Ariel and Alouette, were successfully launched. Actively underway is the San Marco cooperative program with the Italians which is expected to culminate in the first launching of a scientific satellite into an equatorial orbit from a complex of towable platforms located in the Indian Ocean. Cooperative sounding rocket launchings were made from Wallops Island and from stations in several foreign countries. Forty-four nations have united with NASA in various ground-based programs in experimenting with satellites in meteorology and communications. Thirty-eight scientists at the postdoctoral level from 19 countries have participated in work at NASA centers. Nineteen fellows sponsored by the national space committees are working at U.S. universities engaged in space research programs. Some 48 technicians supported by their home-sponsoring agencies have come to the United States from 14 countries for training in project-related activities such as sounding rocket launchings, tracking, and payload design and preparation. The growth of the international programs is expected to continue. The participating countries pay the costs of their own participation, and thus contribute both manpower and funds to scientific projects of mutual interest.

In conclusion a word should be said about the role of universities in the space program. Recognition of the universities' capabilities in scientific and engineering research is reflected in the substantial amount of project support for the conduct of space research by university groups. Such projects range from theoretical studies to the design and engineering of experiments to be flown on satellites and space probes. This support is being continued and augmented wherever the job is best done in the university environment. Beginning in fiscal year 1962, in the belief that university participation in the space program could be strengthened and that NASA should contribute to some extent to the resupply of the competent scientists and engineers needed in its future program, NASA inaugurated the sustaining university program. The sustaining university program includes grants to support selected research programs, grants to provide under certain circumstances the provision of additional laboratory space and equipment, and training grants. The research grants are intended to increase the level of activity in small but promising research areas, and particularly to stimulate broad new multidisciplinary research investigations in such fields as magnetogasdynamics, plasma physics, and materials. Where additional laboratory space is urgently needed to conduct research in space-related science and technology and the institution involved has indicated its intent to seek ways in which the benefits of the research can be applied to the social, business, and economic structure of the United States, NASA may provide funds for the acquisition of research facilities. We are particularly desirous that the effort be multidisciplinary, drawing upon creative minds from various branches of the sciences, technology, commerce, and the arts. Training grants are available to qualified universities for the selective support of predoctoral graduate students in appropriate areas of study. These grants are made to universities, not to separate departments or to individual students. It is the responsibility of the university to select for participation students of unusual promise with interest in space science and technology.

In this program an attempt is made to secure a reasonable stability of operation. Thus the predoctoral training grants are made for 3 years, but individual performance is reviewed annually. A student who maintains a satisfactory record with the university is assured of the opportunity to continue his training for a second and a third year. Similarly, the initial research grants are 3-year grants for support at the required level of effort during the first year, two-thirds for the second year, and one-third for the third year. Each year the program is reviewed and if satisfactory progress has been made the support is extended forward an additional year.

The present trainee program includes approximately 800 trainees at about 90 universities at a total cost of $15 million. These added to the 100 initiated in fiscal year 1962 will make about 900 students in training by the fall of 1963. Our ultimate goal is to have about 4,000 students in training leading to about 1,000 graduating each year.

The budget for fiscal year 1963 for the sustaining university program is $30,600,000 and the fiscal 1964 budget is $55 million.

In summary, the objectives and missions of NASA have been reviewed and future trends discussed. It is noted that proposed manned missions beyond lunar landing are under study in the areas of more extended exploration of the moon, manned earth orbiting laboratory, and manned reconnaissance of the planets. The latter is dependent on results from a manned orbiting laboratory. The many concepts for a lunar station and for a manned orbiting laboratory range from very modest advances to more ambitious projects, and clarification is needed of the objectives, justification, and requirements, which we hope will result from studies underway or to be initiated.

Future trends in other areas are discussed as well as specific milestones of the next few years. A brief review has been given of the aeronautics, international, and university programs.

3 The Fiscal Year 1964 NASA Budget Requests

DEMARQUIS D. WYATT
Director, Office of Programs

A general overall view of the programatic makeup of the 1964 program was given in the preceding paper by Dr. Dryden. Subsequent papers will deal with sections in detail. The purpose of this paper is to tie together, in a very gross fashion, these programs and the President's budget request to the Congress.

Table 3–I summarizes the total of the President's request for 1964. Actually, we seek two subappropriations from the Congress: Research, Development, and Operations, totaling $4,912 billion, and construction of facilities, totaling $800 million.

TABLE 3–I.—*Budget Summary, FY 1964 (millions of dollars)*

Research and Development	$4, 352
Operation of Installations	560
Total, RD & O	4, 912
Construction of Facilities	800
Grand total	5, 712

TABLE 3–II.—*Research and Development, Summary (millions of dollars)*

Office of Manned Space Flight	$2, 932
Office of Space Sciences	738
Office of Applications	119
Office of Advanced Research and Technology	331
Office of Tracking and Data Acquisition	232
Total	4, 352

Table 3–II shows the summary of the research and development appropriation request; these are the monies for the conduct of projects and expenditures outside NASA by the program offices. Approximately 70 percent of the research and development program will be conducted by the Office of Manned Space Flight in the furtherance of the overall manned flight program. The next largest category is that of the Office of Space Sciences, with the other three program offices having relatively smaller parts of the total program.

TABLE 3–III.—*Office of Manned Space Flight, Research and Development (millions of dollars)*

Manned Spacecraft Systems	$1, 557
Launch Vehicles and Propulsion Systems	1, 168
Aerospace Medicine	17
Integration and Checkout	153
Systems Engineering	37
Total	2, 932

Table 3–III shows a breakdown of funds in the Office of Manned Space Flight. Our Manned Spacecraft Systems constitute a little over $1.5 billion of the President's request for fiscal year 1964. The Manned Spacecraft Systems funds include all the expenses of the Gemini and Apollo projects, including the launch vehicles for the missions as well as the development of the spacecraft and associated operating costs.

Launch Vehicles and Propulsion Systems, at approximately $1.2 billion, represents the effort in fiscal year 1964 on the development of the very large launch vehicles Saturn I, Saturn IB, and Saturn V and the associated new engine developments, principally the F–1 and the J–2 engines. Also included is the effort that we are conducting on the M-1 engine development project, not now linked to hardware development for a specific Nova vehicle. There are no funds in this budget request for the hardware development of the Nova vehicle.

Aerospace Medicine, in comparison with the other programs, is relatively small; it covers the work in the aeromedical area required to accomplish the manned space flight program.

Integration and Checkout covers the work indicated by the title plus the general quality assurance activities in the Office of Manned Space Flight. A large portion of the $153 million shown is for the purchase of equipment to execute the integration, checkout, and general reliability work.

Systems Engineering, the last category, is largely the purchase of studies and services on behalf of the operation of the major complex of projects in the Office of Manned Space Flight. This area includes the study moneys for the advancement of potential projects discussed by Dr. Dryden in paper 2.

Table 3–IV shows a similar breakdown of funds for the Office of Space Sciences. The Geophysics and Astronomy program, which embraces all our earth satellites in the scientific exploration of space, is budgeted at just under $200 million. (Each of these categories includes not only the spacecraft and operations cost, but also the launch vehicle cost required for the accomplishment of the mission.)

TABLE 3–IV.—*Office of Space Sciences, Research and Development (millions of dollars)*

Geophysics and Astronomy	$194
Lunar and Planetary Exploration	323
Bioscience	35
Launch Vehicle Development	131
Sustaining University Program	55
Total	738

Our Lunar and Planetary Exploration program, at $323 million, includes the Ranger and Surveyor in the lunar programs and the Mariner spacecraft in the planetary programs, as well as studies for advanced lunar and planetary missions. For these advanced projects no funds are allotted beyond the study level.

The Bioscience program is for the flight of unmanned bioscience satellites. Detailed discussion of this program will be given in subsequent papers.

The Launch Vehicle Development is primarily for the ongoing development of the Centaur medium launch vehicle, although funds are also included for the product improvement and for the production tooling of other light and medium launch vehicles that are used in the overall NASA program.

The Sustaining University program has a proposed budget of $55 million. The training grants that NASA makes in this area are on a no-strings basis; the resultant graduates are under no special commitment to stay either with NASA or with the Government, and hence will offer a pool of talent to industry as well.

Table 3–V shows the breakdown of funds for the Office of Applications. The Meteorological Satellites program, funded by NASA at $63 million, will be augmented by funding sought directly by the Weather Bureau, U.S. Department of Commerce, in the Nimbus operational satellite area.

TABLE 3–V.—*Office of Applications, Research and Development (millions of dollars)*

Meteorological Satellites	$63
Communications Satellites	51
Other Applications	5
Total	119

The Communications Satellites program, $51 million, is again only NASA's share of the overall national communications satellite program and the overall program will also include, presumably, activities by the Communications Satellite Corp., as well as the work being done by the Department of Defense.

The Other Applications category is budgeted at $5 million; its funds would be used to further the feedback of the technical information acquired by NASA in all areas to the general industrial economy of the country, as well as to study other applications for which space may be suited beyond the areas of meteorology and communications.

TABLE 3–VI.—*Office of Advanced Research and Technology, Research and Development (millions of dollars)*

Space Vehicle Systems	$62
Electronic Systems	30
Human Factor Systems	18
Nuclear-Electric Systems	69
Nuclear Rockets	97
Chemical Propulsion	22
Space Power	17
Aeronautics	16
Total	331

Table 3–VI shows a breakdown of the moneys that will be administered by the Office of Advance Research and Technology. These programs, for the most part, do not have comprehensive flight programs associated with them, although there are some specific smaller flight missions. In general, this is the purchase of an advanced technological base for the country for the enhancement of future exploration and utilization of space. Each one of these areas will be discussed in more detail in subsequent papers.

Table 3–VII shows the moneys required for the Office of Tracking and Data Acquisition which supports all programs of NASA. Over half the budgetary request is for equipment for the updating of and additions to existing tracking networks; equipment necessary for the accomplishment of the more advanced flights that are programed for the future.

TABLE 3–VII.—*Office of Tracking and Data Acquisition, Research, and Development (millions of dollars)*

Operations	$81
Equipment	134
Advanced Development	17
Total	232

Table 3–VIII shows a general breakdown of the budget requested for the Operation of Installations and for the Construction of Facilities. In the area of operation of installations, about 60 percent of the total is for the payment of personnel costs and expenses, that is, the salaries and associated expenses of the in-house NASA personnel. About 40 percent of the total is for the purchase of supplies, equipment, and services by the individual installations in order to give them a going research capability. This money goes out directly on contract, as does our project money.

Although these items will not be discussed in detail herein, it may be pointed out that at the Launch Operations Center, the construction of facilities comes to $313 million. This provides for construction at the Atlantic Missile Range, Cape Canaveral area, particularly the construction on the new Merritt Island launch complex operated by the Launch Operations Center. The great bulk of this money is for construction facilities associated with the Saturn and Apollo programs. As shown in table 3–VIII, the Marshall Space Flight Center is still the principal office for the Michoud plant and the Mississippi Test Facility, and the operations costs are combined. There is a very healthy construction program at the Mississippi Test Facility, again in support of the large vehicle and Apollo programs.

TABLE 3–VIII.—*Operation of Installations and Construction of Facilities (millions of dollars)*

	Operations	CoF
NASA Headquarters	$66	------
Ames Research Center	31	$13
Flight Research Center	10	4
Goddard Space Flight Center	68	21
Jet Propulsion Laboratory	------	7
Langley Research Center	54	10
Launch Operations Center	37	313
Lewis Research Center	66	26
Manned Spacecraft Center	71	38
Marshall Space Flight Center	132	38
Michoud Plant		10
Mississippi Test Facility		112
North Eastern Office	11	------
Nuclear Rocket Development Station	------	20
Pacific Launch Operations Office	1	------
Space Nuclear Propulsion Office	2	------
Wallops Station	10	2
Western Operations Office	7	------
Various Locations	4	186
Total	560	800

The last category, Various Locations, shows an operations cost of $4 million. This is for the contemplated operation of the Electronic Research Center to be located in the greater Boston area. It is listed technically as "Various Locations" at this time, however, because the site has not been authorized by the Congress. Also included under Construction of Facilities at Various Locations is $5 million for initial land purchase and initial site planning and development. We do not propose to start actual construction of this site in fiscal year 1964, but we do hope to get our master planning done and to procure the site.

Individual programs and specific budgetary requests will be outlined in detail in subsequent papers.

4 The NASA Organization

ALBERT F. SIEPERT

Director of Administration

The civilian space program has been characterized by very rapid growth and change in the number of programs undertaken, the fund resources to implement these programs, and, to a lesser extent, the organizational structure and manpower needed to plan, direct, and evaluate the overall effort. The organizational rearrangements within the NASA have been handled by gradual evolution rather than drastic change. The purpose of this paper is to describe the current physical structure of this agency.

Achieving a manned lunar landing and return before the end of the decade is said to be the greatest single technological objective yet attempted. No single Government agency could encompass this objective through only its own efforts, and yet the NASA program includes a number of other goals besides those related solely to manned space flight which are highly important for aeronautics and space exploration. A program of such scope and complexity requires integrating the skills of thousands of people in Government agencies, universities, and industrial concerns. Very large sums of money are involved. Especially for those in private industry who participate in this team effort, it may be helpful to explain the organization NASA has developed to handle its direction of the total task.

BASIC ORGANIZATIONAL CONCEPTS

Since the start of NASA in 1958, its leadership has followed a policy of maintaining an exceptionally strong technical competence within its own laboratories. This was a natural outgrowth of its inheritance from its predecessor agency, the National Advisory Committee for Aeronautics, which had built an enviable international reputation for research accomplishment. NASA has felt that Government representatives, rather than contractors, must make the basic determinations of what is to be done with public funds. This means attracting and holding a reasonable share of the country's creative and managerial talent. It means a career staff sufficient to accept full responsibility for any specification for the hardware work done outside NASA and sufficient to assure effective contractor performance under such specifications.

In view of the head start the Russians had with their own space efforts, there would not have been time to custom build such a staff from scratch. The major portion of NASA's present staff all came into the new agency through provisions of law or Executive Order effecting mass transfers of existing organizations (see fig. 4–1): 8,000 employees from the National Advisory Committee for Aeronautics; 200 from the Vanguard Office of the Naval Research Laboratory; 4,300 employees who comprised the Von Braun rocket team plus 1,200 supporting personnel from the Army Ballistic Missile Agency; and 2,400 contractor employees (not shown in this figure) who were engaged at a Government-owned facility, the Jet Propulsion Laboratory, in rocket work for the Army under contract with the California Institute of Technology.

The NASA leadership was obliged, therefore, to build its staff while at the same time it had to complete a variety of space projects initiated by other agencies; also new projects

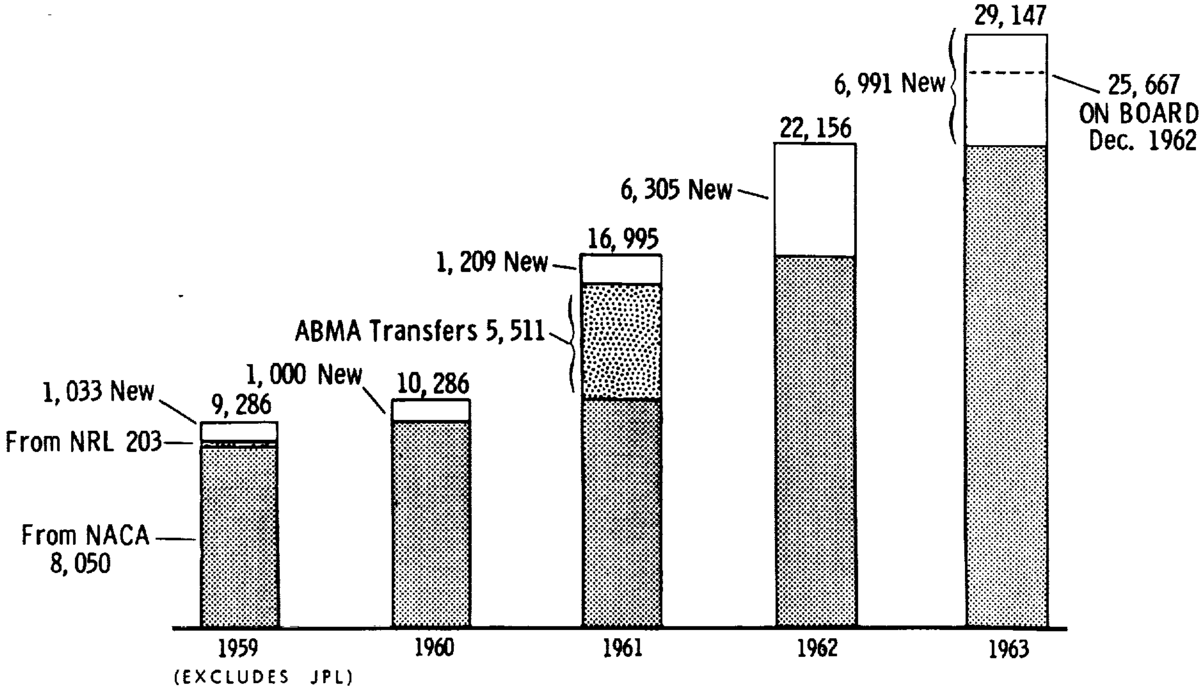

FIGURE 4-1.—NASA personnel growth, fiscal year 1959 to fiscal year 1963.

had to be conceived to assure much greater payoffs in later years. This task of preparing for a race already being run would have been impossible, except that NASA was permitted to take over *intact* as much of the existing organized aerospace competence in Government as could be spared without disrupting the ballistic missile and aerospace capability for national defense.

The organization today consists of eleven major field centers or stations, two regional field offices, and a Washington headquarters, together comprising as of December 1962, some 25,667 employees, of which 9,240 are professionally trained scientists or engineers. One additional field center is now proposed in the current fiscal year 1964 budget estimate before the Congress. This is a new center to equip NASA with a basic competence in research and advanced technology in the field of electronics. It is proposed that this center be located near the university and industry concentration in electronics in the metropolitan Boston area.

NASA's work in its field centers embraces research into practicaly every problem of aeronautical and space flight as well as experimentation in the sciences which undergird exploration of the universe. All NASA's field centers are equipped, insofar as practicable with the most advanced research and testing facilities which can be designed and built today. NASA feels that it is essential to engage in a sufficient amount of basic and applied research on an in-house basis to keep the entire staff immediately abreast of the advancing technology.

However, the bulk of its basic research is financed through grants or contracts to universities, just as the bulk of the applied research or advanced technology is handled by contract with industry or nonprofit institutions.

NASA executes its hardware development program primarily through private industry. There are a series of approved "projects," currently over 40 in number. These would be roughly equivalent to a "weapons system" in the Department of Defense.

The NASA systems management responsibility at the operating level is assigned to research and development field centers. Although increasing proportions of such staffs are devoting their full time to engineering development, their ready access to research colleagues in the laboratories is invaluable. Their prime efforts, however, are directed to the technical supervision and evaluation of the work placed on contract with industrial concerns and, to a lesser extent, with nonprofit institutions and universities.

THE FIELD ORGANIZATION

The NASA field installations are located at various points widespread across the country. (See fig. 4–2.) Most of the NASA field installations are multipurpose in that they contain capabilities which feed into many areas of aeronautics and space technology. Some centers, like Langley and Ames, are more heavily engaged in working on research problems rather than on development projects; others, like the Marshall Center or the Manned Spacecraft Center in Houston, are primarily engineering development teams. Each center, however, has a primary focus in one or more substantive areas of the NASA program, and each arranges for extensive and close exchange of its information with related groups in other centers.

The oldest laboratory is the Langley Research Center at Hampton, Va., where much of the NASA research work in aerodynamics, flight mechanics, spacecraft technology, and materials and structures is located, as well as certain hardware development projects such as the Scout launch vehicle and the Echo communications satellite.

Near Washington, D.C., in Greenbelt, Md., is the Goddard Space Flight Center. This laboratory houses NASA's principal research and development enterprises in sounding rockets and earth satellites; it also is the nerve center for tracking computation and data reduction for all NASA earth satellites, including Project Mercury.

In Cleveland, Ohio, is the Lewis Research Center, where our work on space propulsion systems (chemical, electric, and nuclear) is concentrated. This center was recently assigned the management of the Centaur and Agena vehicle development as well as the 1-million-pound M–1 hydrogen-fueled engine.

The largest NASA installation, the Marshall Space Flight Center in Huntsville, Ala., is engaged in developing the large Saturn launch vehicles. It is closely linked geographically with three other NASA sites: the Mississippi Test Facility, the Michoud facility near New

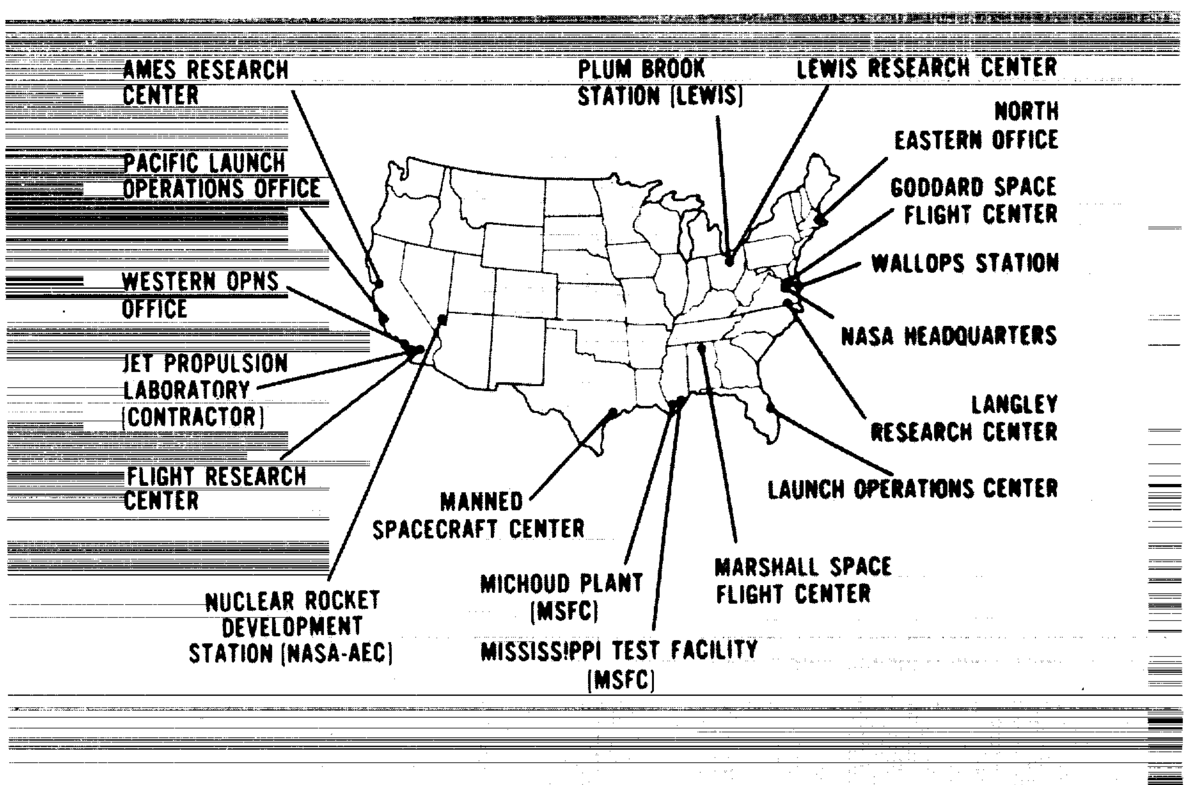

FIGURE 4–2.—NASA installations.

Orleans, and Cape Canaveral. (See fig. 4–3.) At Michoud the Saturn I and V first stages are being built by private contractors (Chrysler Corp. and The Boeing Co.) under monitoring by the Marshall Center team. Thirty-five miles away at the Mississippi Test Facility, the various stages of these large launch vehicles will be static-tested. The two sites were selected on deep waterways on the Gulf coast so that it would be a relatively easy matter to transport these outsized stages (some are 33 feet in diameter) by barge between the fabrication and testing sites, and finally to the launching sites at Cape Canaveral.

In Houston, Tex., is the new Manned Spacecraft Center. Here is located the headquarters for the remaining flight of Project Mercury, for engineering development and operation of Project Gemini, and later the Project Apollo spacecraft.

The Ames Research Center, near Palo Alto, Calif., is concerned primarily with spacecraft technology, high-speed reentry research, and some aeronautical research, and has the beginnings of a modest NASA staff with special research interests in the biosciences. Ames is currently well advanced in its plans to undertake the direction of a few flight development projects, such as the quiet sun solar probe Pioneer or "PIQSY."

The Flight Research Center at Edwards, Calif., handles research programs involving high-speed flight. The highly successful X–15 project, a joint NASA-Air Force effort, has

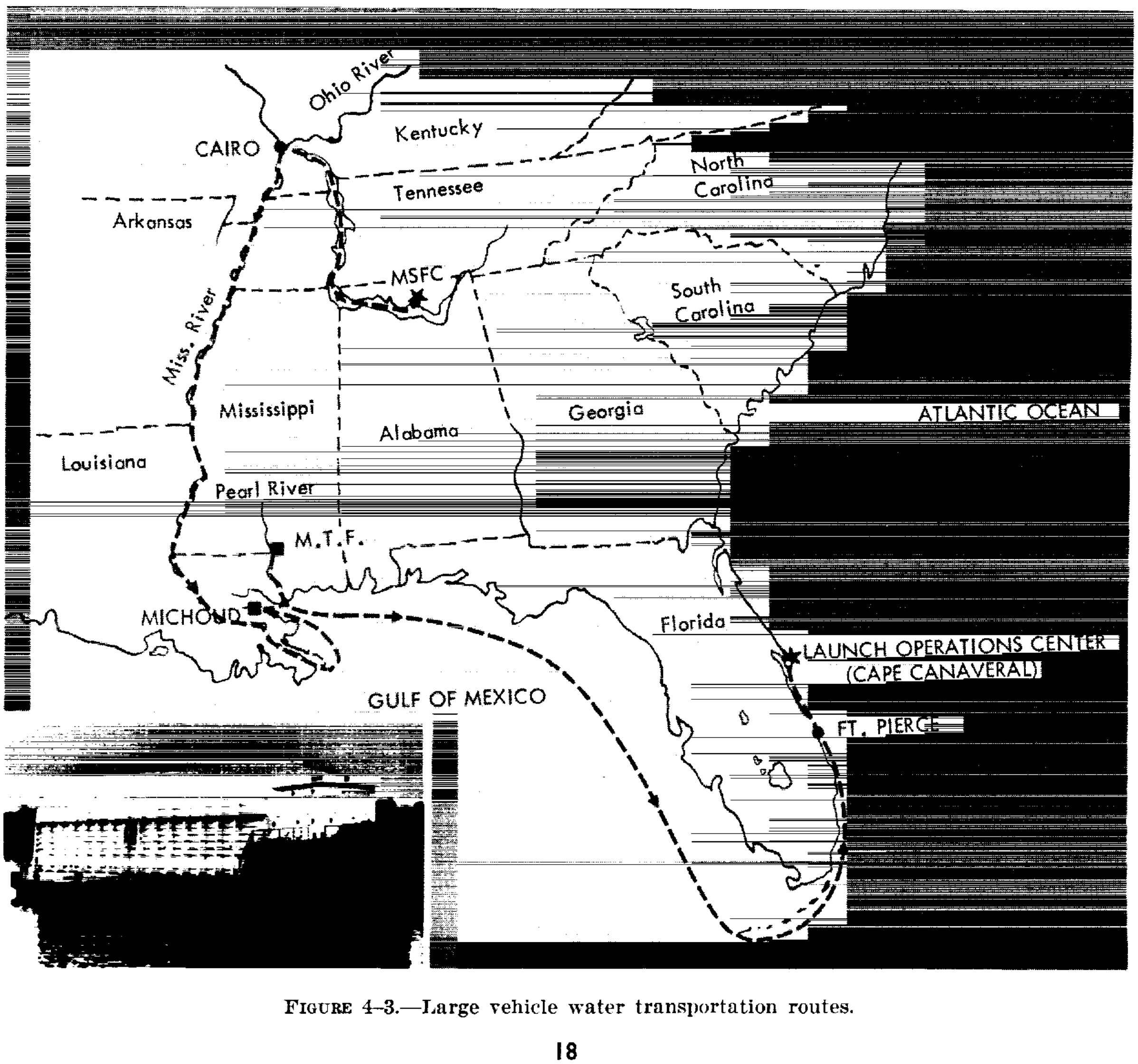

FIGURE 4–3.—Large vehicle water transportation routes.

been managed and carried out by the Edwards team.

At Pasadena, Calif., is the Government-owned facility used by the California Institute of Technology in its operation of the Jet Propulsion Laboratory. It is responsible for executing NASA's principal missions in the field of unmanned lunar and planetary missions, such as the current Ranger and Mariner shots, and for operating NASA's deep space tracking network consisting of large 85-foot dishes at Goldstone, Calif., Woomera, Australia, and Johannesburg, South Africa.

NASA flight missions are launched primarily from three locations. The most prominent is Cape Canaveral where the Launch Operations Center coordinates NASA activities with those of the Air Force, since both use the common facilities of the Atlantic Missile Range.

On the Virginia capes is Wallops Station. It is equipped to launch all types of sounding rockets as well as NASA's Scout, a solid-fueled launch vehicle.

Finally, at Point Arguello, Calif., is the NASA Pacific Launch Operations Office. This handles NASA polar orbiting flights on the Navy's Pacific Missile Range, using Delta and Agena stages on top of Thor and Atlas vehicles, respectively.

NASA has two area offices which handle on a local basis some of the NASA business which affects contractors in a given region. The Western Operations Office in Santa Monica, Calif., performs technical liaison and selected contract administration services at the request of the various field centers which have placed work with the various contractors in the Western States. A similar office was recently opened in Boston, Mass., and is known as the North Eastern Office. Both of these offices will try to furnish any NASA procurement information sought by local businesses.

The majority of the contracts awarded by these NASA installations are placed with the same business firms which are heavily involved in Department of Defense R&D contracts. Therefore, the closest cooperation between DOD and NASA becomes essential. NASA makes extensive use of the in-plant contract administration and audit services of the Army, Navy, and Air Force for all but a few critical major contracts. Nonetheless, NASA feels responsibility in assuming the direct contract negotiation and initial award for all NASA work except for the procurement of items of hardware which may be in the weapons systems production lines and the furnishing of certain common services. As a result, NASA awards about 75 percent of its business directly; the rest is handled through the DOD.

CURRENT ORGANIZATION STRUCTURE

Through experience gained over the last 4 years, NASA has made gradual improvements in its organizational structure to carry out these flight development projects and the necessary supporting research and advanced technology.

The top direction of NASA's affairs is vested in a three-man team which collectively assumes responsibility for the major technical, managerial, or contractual decisions undertaken by the space agency. (See fig. 4-4.) The Administrator, James E. Webb, and the Deputy Administrator, Dr. Hugh L. Dryden, are Presidential appointees. The third member is the Associate Administrator, Dr. Robert C. Seamans, the agency's "general manager," who sees that the entire program is implemented. He is assisted by three Deputy Associate Administrators and by two staff resources, the Office of Programs and the Office of Administration. The Office of Programs is the agency's "budget office" which coordinates all resource programing for short-term or intermediate periods. (The longer range planning is handled by an Office of Plans and Program Evaluation, which reports directly to the Administrator. Other functions which report to the Administrator, but are not shown in figure 4-4, include: the General Counsel who also has responsibility for the NASA patent program; the Office of International Programs; the Public Affairs activities under an Assistant Administrator; an Office of Legislative Affairs; and a staff official known as the Assistant Administrator for Management Development.). The Office of Programs also has special staffs in the fields of technical analysis, management reporting, facilities coordination, and reliability and quality assurance procedures. The Office of Administration oversees the development and execution of agencywide policies in procurement, personnel administration, financial management, security, management analysis, audit, and inspection services.

In Headquarters, there are four technical program offices in the fields of Space Sciences, Applications, Advanced Research and Technology, and Manned Space Flight. In addi-

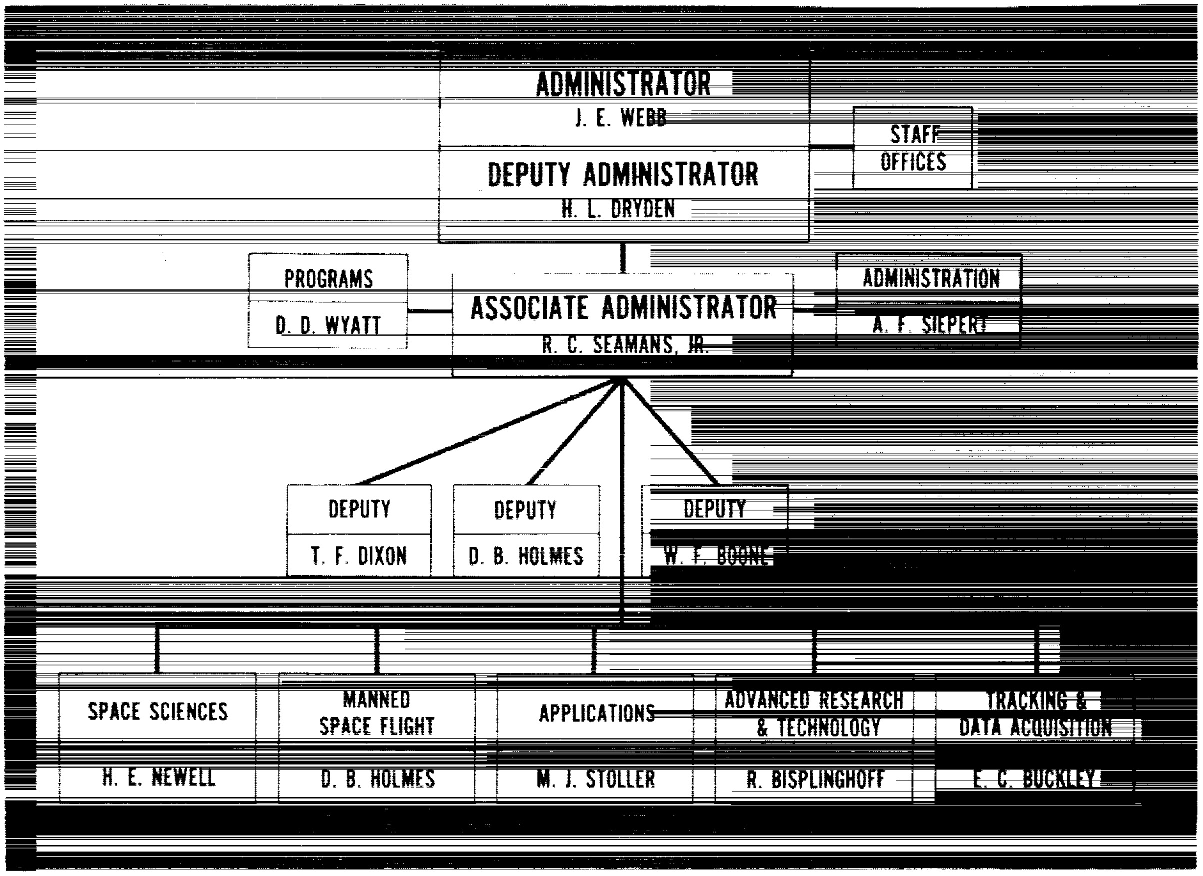

FIGURE 4-4.—NASA Headquarters organization.

tion, a technical support office handles all Tracking and Data Acquisition systems. These five directors have been given technical and budgetary control over project resources which they assign in turn to one or more of the NASA field centers for execution. (See fig. 4-5.) Each program office is staffed with engineers and scientists to program the overall scope of the project and keep continuously abreast of its scheduling, funding, and performance requirements. Details of their internal organization and functions will be presented in subsequent papers.

The NASA field centers are responsible for reporting directly to the several program offices on the accomplishment of their assigned projects. Each center designates a Project Manager who has responsibility for technical supervision of the work of the several contractors, for assuring that there are adequate systems engineering and integration of the developed hardware, and for assuring that schedules and cost estimates are kept as closely as possible. The directors of the field centers, however, report directly to the Office of the Associate Administrator in all institutional or nonproject matters. One of the Deputy Associate Administrators handles center operations for three installations primarily concerned with manned flight (i.e., Manned Spacecraft Center, Marshall Space Flight Center, and Launch Operations Center). The second Deputy Associate Administrator takes care of the institutional problems for all other field centers. The third Deputy assists the Associate Administrator in the many continuing relationships involving defense affairs.

This type of organizational structure stresses project control through one channel (the Program Offices) and overall institutional accountability through another channel (the Office of the Associate Administrator). A matrixed

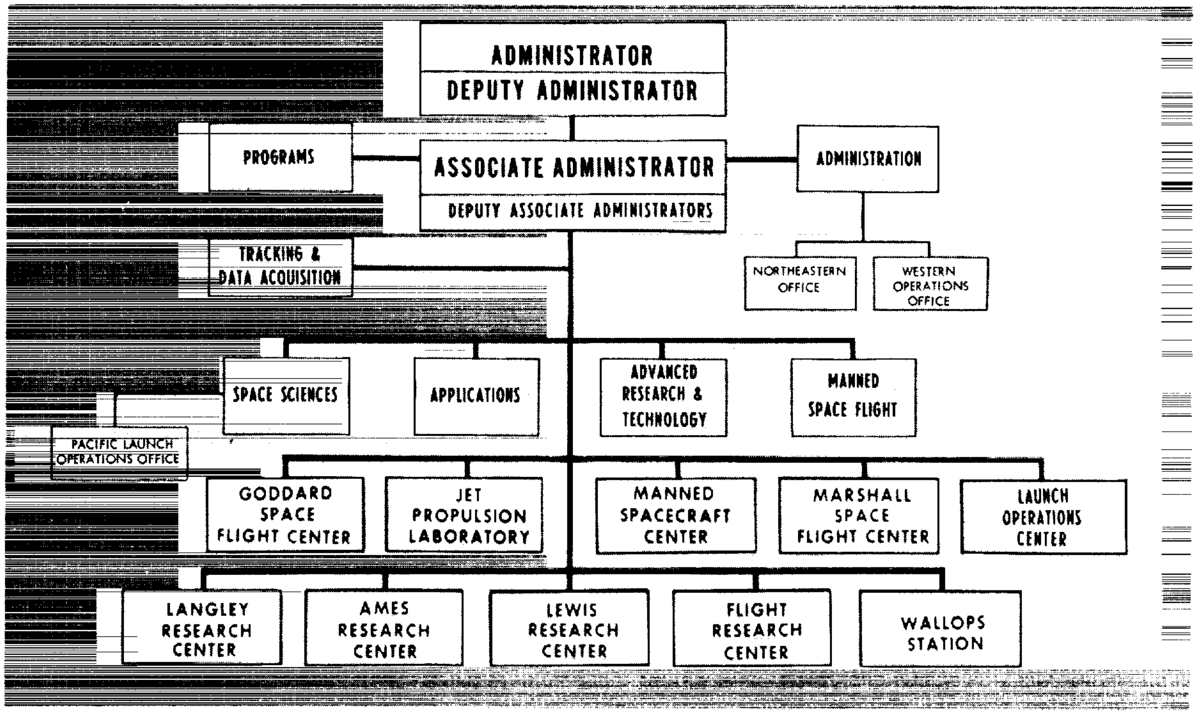

FIGURE 4-5.—NASA operating organization.

organization of this type is not unique to NASA. This type of organization was introduced by the necessity for organizing functionally in an economic manner the many technical skills involved and at the same time providing a project overlay with the necessary responsibility to integrate these skills so that a most complicated systems development is completed well, on schedule, and within the budget.

There is more than one way to structure a solution to this problem, and in NASA there are no illusions that any perfected optimum and permanent arrangement has been reached. No doubt some additional experience will be acquired which will suggest improvements through further change. Hopefully, these changes can be effected without major unheaval or loss in the pace of our program. In fact, the several organizational adjustments made since 1958 have all been essentially evolutionary, rather than catastrophic "new deals."

Organizational change in a rapidly evolving program such as NASA's is not nearly so difficult as in an organization with long established goals, a stabilized budget, and a leadership with a vested interest in resisting change. By the very nature of its task, an R&D organization provides an atmosphere of excitement, unpredictability, and readiness for change. As a result, there is an open ear for ideas which may simplify our lines of managerial control and decision. It is recognized that an enormous number of people now have a deep interest, financially and otherwise, in what NASA is trying to accomplish. We believe that the current NASA organizational structure can assist in establishing a fruitful relationship for both the Federal Government and private industry.

5 Introduction to Manned Space Flight Program

D. BRAINERD HOLMES
Director, Office of Manned Space Flight

The manned space flight program includes Mercury, Gemini, and Apollo. It also includes the development of large launch vehicles. Recently, NASA made a minor change in the designation of the Saturn-class launch vehicles. For clarification purposes, they are now called the Saturn I, which was the Saturn C–1, the Saturn IB, which was the C–1B, and the Saturn V, formerly the C–5. The Saturn IB will have a new second stage with a single J–2 engine, which will provide a capability of boosting into earth orbit a payload of some 32,000 pounds, as contrasted with 22,000 pounds in the Saturn I. The Saturn V will provide earth-orbit capability of 240,000 pounds.

We have almost completed the detailed scheduling necessary for the control of the Apollo program. The effort has taken about a year. It is not completely finished, but we have reasonable indication of what we need in funds. Of course, we depend heavily upon the estimates, made by industry, and upon the accuracy with which industry arrives at these estimates. I think we have gone very far in establishing contracts, and in establishing the specific goals that we will meet over the years ahead. Dr. Shea's paper will highlight some of these goals and complement some of the information that is in Dr. Hugh Dryden's paper.

Only a few years have passed since October 1957, when the first Sputnik was launched. If one had then said that we would be going to the moon within a few years, the statement would have been greeted with laughter. We have come rapidly in this short time. NASA is expending a large share of the national resources, not only in dollars, but in skilled personnel, which is perhaps an even scarcer commodity. I think that one has to draw a balance between what we are spending today and what we will do in the future. However, I feel strongly that an effort of the proportions of the present national space program would indeed be futile if it were not to be followed by a program leading to deeper probes and greater efficiency in space.

one had then said that we would be going to the

In my opinion, there will be a continuing evolution in these programs. I think it is apparent that the rapidity with which they can be carried out will depend directly on the efficiency with which we carry out our present programs, for which the primary responsibility is borne by industry.

The Office of Manned Space Flight is organized into six directorates. Dr. Joseph Shea heads Systems Engineering. Systems Engineering, as used in many parts of American industry, is that group which does three things: first, the overall operations analysis; next, the overall systems engineering planning; and finally, systems engineering monitoring. This approach establishes a path along which progress is followed in depth, from the standpoint of technology and of the technical marriage of all parts of the system. Included in systems engineering are such things as reliability analysis. I mention this because we have a separate Office of Integration and Checkout, which primarily has the responsibility of implementing the aspects of reliability analysis that are determined and established by the Systems Engineering group.

The second director, Mr. Low, heads Spacecraft and Flight Missions. This directorate has a very close and direct interface with the field center primarily responsible for that work, the Manned Spacecraft Center at Houston.

Mr. Rosen is Director of Launch Vehicles and Propulsion. In that directorate, the engines are developed, as well as the stages for our large launch vehicles for the manned lunar program. That office has a close and direct relationship with the Marshall Space Flight Center, the field center charged with that responsibility.

In the way NASA is organized, almost all of the contracts to industry go out through the field centers. The few exceptions are in Dr. Shea's Office of Systems. These exceptions include studies of advanced research and technology, and matters of a related nature, which happen to be handled by the Office of Manned Space Flight. The function of this program office, as we see it, is that of primary integration. We do not see it as a headquarters, although we do have the function of arriving at the budgets and presenting our program to the Congress. We look to the field centers to integrate their phases of the program and to work with the contractors responsible to them. Then, in the Office of Manned Space Flight, we provide overall integration—or give-and-take in a cooperative way—by pulling the work of the centers together toward the overall program.

The fourth Director is Mr. Lilly, who is in charge of Program Review and Resources Management. In industry that function would probably be termed "internal administration." However, this function includes, and his paper will primarily concern itself with, the establishment of our facilities. Facilities management is performed by a civil engineering group which takes the technical requirements from the other offices. The group monitors facilities establishment and works, in general, with the Corps of Engineers—but in some cases, directly with the field centers—and then with the contractors. This office also establishes and controls all of our budgets and implements the scheduling program, although much of the information comes from the centers and the program directorates in the Office of Manned Space Flight.

The next directorate is Integration and Checkout, headed by Mr. Sloan. This is an area that in some cases is hard to define.

In Checkout, we plan to have an integrated launch complex at the Launch Operations Center in Florida. We hope to employ digital data throughout. Of course, the information will originate in the sensors at the flight vehicles or spacecraft. We hope to have the design of this checkout equipment compatible with the type of visual checkout equipment being used at each of the industrial plants. Then, in the case of launch vehicle stages, the same type of equipment would be used at the Mississippi Test Facility.

Checkout, once established in an integrated manner, tends to extend across the interfaces of any program. Consequently, this office does have the responsibility for the implementation of the reliability program and the integration program. In Integration, we establish across the interfaces that we have compatibility, whether it is electrical signal flow, mechanical signal flow, hydraulic signal flow, and so on.

The sixth and final office is space medicine, headed by Dr. Roadman, whose function is well described by its name.

There are three field centers with primary responsibility for manned space flight, although virtually all of the NASA field centers are participating in the program. The three are the Marshall Space Flight Center, the Manned Spacecraft Center, and the Launch Operations Center.

There is a Management Council in the Office of Manned Space Flight, composed of Directors and Deputy Directors of these three field centers, and the Directors in the Office of Manned Space Flight. From the Manned Spacecraft Center in Houston, the members are Dr. Gilruth, Mr. Williams, and Mr. Elms, who recently became Deputy Director for Research and Development. Mr. Williams is Deputy Director for Flight Operations. From Marshall Space Flight Center, the members are Dr. von Braun and his deputy, Mr. Rees. From Launch Operations Center, we have Dr. Debus.

From the Office of Manned Space Flight, we have Dr. Shea, Mr. Low, Mr. Rosen, Mr. Lilly, Mr. Sloan, Dr. Roadman, and myself. All of these men, in addition to exercising their particular functions, bear direct responsibility for the total success of the manned space flight program.

We talk rather glibly about this tremendous program we are launching. Nevertheless, I think it is under control, and I think a great deal has been done in its organization, thanks in large part to industry.

This program is an adventure that staggers man's imagination. It is a venture that treads into realms in which man has not previously trod. We need the help of those in industry and the help of those in Government working very closely together to do the job that is before us.

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6 Manned Spacecraft and Flight Missions

GEORGE M. LOW
Director, Spacecraft and Flight Missions, Office of Manned Space Flight

Slightly more than 2½ years ago, at the first NASA-Industry Program Plans Conference in July of 1960, Project Apollo was discussed for the first time. The following quote was taken from the proceedings of that conference.

In this decade, therefore, our present planning calls for the development and construction of an advance manned spacecraft with sufficient flexibility to be capable of both circumlunar flight and useful earth-orbital missions. In the long range, this spacecraft should lead toward manned landings on the moon. . . .
In the near future, industry will be invited to participate, by contract, in a program of system design studies. According to present plans, a systems contract for the design, engineering, and fabrication of the manned spacecraft and its components will probably be initiated in fiscal year 1962.

A great deal has been accomplished in the intervening 2½ years. In 1962, the objectives of Project Mercury were achieved. The Gemini program, which had not been planned at the time of the previous conference, is now well underway. The industry studies and development contracts for Apollo were initiated on the schedule discussed at the last conference. However, a major change in the Apollo program has taken place in the intervening time: In 1960, a circumlunar flight was planned; whereas in 1961, approval was given to extend this mission to a manned lunar landing.

The purpose of this paper is to discuss the status of these projects, to describe a number of specific problem areas, and to describe the NASA organizational structure which provides the detailed technical direction for these projects.

PROJECT MERCURY

The objectives of Project Mercury were to take this Nation's first step in a manned exploration of space, to determine man's capabilities in space, and to develop the foundation for the technology of manned space flight. These objectives were all met in a program of 21 flight tests, some manned and some unmanned (table 6–I).

From this program of 21 flights, we have learned such things as:

(1) How to design, build, and test spacecraft which will carry a man in an orbit more than 100 miles above the surface of the earth.

(2) How to adapt the launch vehicle, originally not intended for manned flight, to be sufficiently safe and reliable to permit its use in manned space flight.

(3) How to plan and implement a worldwide, ground-based tracking network which will maintain close control over the flight operations, and how to conduct real-time operations of manned spacecraft.

(4) How to select and train astronauts to conduct flights which are unforgiving of any major error in judgment or performance.

(5) How to design and provide equipment which will enable man to live in the hostile environment of space.

(6) Most important of all, we have learned that man can perform useful functions in space

TABLE 6-I.—*Project Mercury Flight Test Results*

Date	Designation	Mission objectives	
		Accomplished	Not accomplished
Sept. 9, 1959	Atlas-Big Joe	√	
Oct. 4, 1959	Little Joe 1	√	
Nov. 4, 1959	Little Joe 2	Partially	
Dec. 4, 1959	Little Joe 3	√	
Jan. 21, 1960	Little Joe 4	√	
July 29, 1960	Atlas 1	----------	√
Nov. 8, 1960	Little Joe 5	----------	√
Dec. 19, 1960	Redstone 1	√	
Jan. 31, 1961	Redstone 2	√	
Feb. 21, 1961	Atlas 2	√	
Mar. 18, 1961	Little Joe 6	Partially	
Mar. 24, 1961	Redstone Test	√	
Apr. 25, 1961	Atlas 3	----------	√
Apr. 28, 1961	Little Joe 7	√	
May 5, 1961	Redstone 3 (Shepard)	√	
July 21, 1961	Redstone 4 (Grissom)	√	
Sept. 13, 1961	Atlas 4	√	
Nov. 29, 1961	Atlas 5	√	
Feb. 20, 1962	Atlas 6 (Glenn)	√	
May 24, 1962	Atlas 7 (Carpenter)	√	
Oct. 3, 1962	Atlas 8 (Schirra)	√	

and that he can contribute as a test pilot, a flight engineer, and an explorer—just as he does in atmospheric flight.

At present, one more flight is scheduled for Project Mercury. The astronaut for this flight will be Gordon Cooper, and his alternate is Alan Shepard. If this flight, now planned for 1 day's duration, is successful, no other Mercury flights will be made.

PROJECT GEMINI

Hard on the heels of Project Mercury will come the first flights of Project Gemini. This program, which was initiated since the first NASA-Industry Program Plans Conference, is well underway with the first flight scheduled around the end of the year. The major objectives of Project Gemini are to gain operational proficiency in manned space flight and to develop advanced techniques including rendezvous and docking.

The Gemini program was conceived as a bridge between the Mercury and Apollo programs. In order to span this gap quickly, it was necessary that the Gemini spacecraft resemble Mercury in a number of important details (fig. 6–1). Gemini is essentially the same

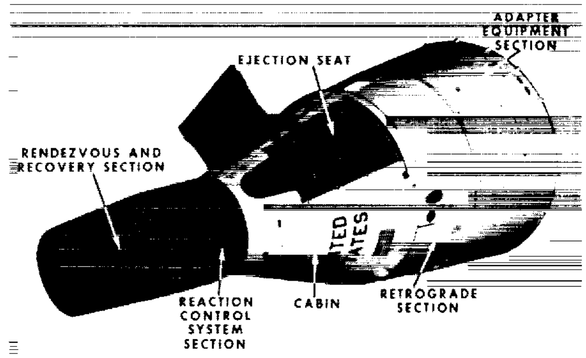

FIGURE 6–1.—Gemini spacecraft.

shape as Mercury, but its size has been increased to accommodate a crew of two. In addition, the adapter section is retained while in orbit. This component provides systems and consumables which will permit longer duration flights with spacecraft maneuvers. As has been the trend in modern aircraft in recent years, the Gemini spacecraft is designed for efficient maintenance by locating spacecraft systems for easy access, checkout, and repair.

It is planned that the Gemini spacecraft will be equipped with a paraglider landing system (fig. 6–2). Following a controlled lifting re-

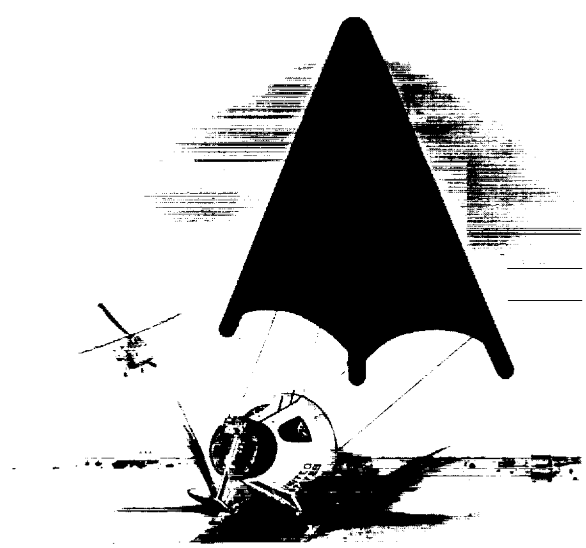

FIGURE 6–2.—Paraglider landing system.

entry, the paraglider will be deployed at approximately 50,000 feet. Ejection seats, borrowed from aircraft industry technology, will be used in case of paraglider malfunctions. Using this system, the Gemini will be flown as a glider to a point landing.

Gemini space suits will have removable boots and gauntlets to provide a maximum degree of comfort to the astronaut during the long duration flights (fig. 6–3). In addition, the

FIGURE 6–3.—Gemini spacesuit.

Gemini spacecraft is designed to permit the astronaut to open a hatch and pass from the spacecraft into the space environment protected only by his space suit. This latter capability will enable him to take the first steps toward outside inspection and possible repair of his own spacecraft.

The launch vehicle for the Gemini spacecraft will be the Titan II. As in the case of the Mercury booster, this launch vehicle will be modified to provide the necessary reliability for astronaut safety.

For the rendezvous flights of Gemini, the target vehicle will be a modified Agena-D which will be inserted into orbit by an Atlas launch vehicle. Based upon ground tracking data, the Agena-D target and the Gemini spacecraft will be brought within approximately 200 miles of each other by ground command. At this distance, control of the rendezvous and docking will be transferred to the astronaut crew. The Gemini spacecraft and the target vehicle will be maneuvered together using the spacecraft radar, visual cues, and the propulsion systems of both vehicles (fig. 6–4).

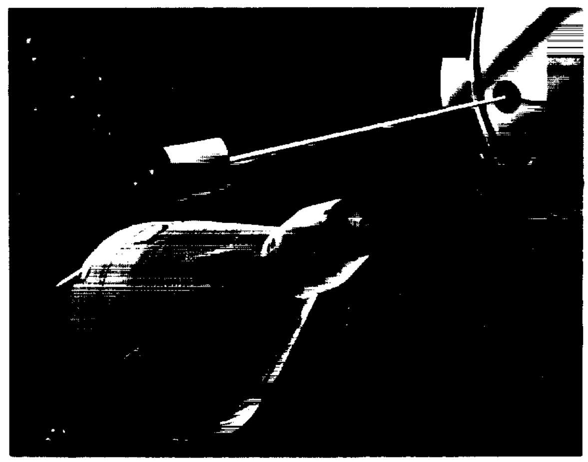

FIGURE 6–4.—Gemini docking.

A total of 12 Gemini flight spacecraft will be built by the prime contractor, the McDonnell Aircraft Corp. McDonnell has already selected a team of subcontractors; therefore, no additional procurements of a significant nature for Project Gemini are planned at this time (table 6–II).

TABLE 6–II.—*Gemini Spacecraft Contracts*

SPACECRAFT PRIME CONTRACTOR	McDonnell Aircraft Corp.
MAJOR SUBCONTRACTORS:	
Guidance Platform and Autopilot	Minneapolis Honeywell
Guidance Computer	IBM
Attitude Control and Maneuver Electronics System	Minneapolis Honeywell
Orbital Attitude and Maneuver System	Rocketdyne
Reaction Control System	Rocketdyne
Rendezvous Radar and Transponder	Westinghouse Electric
Environmental Control System	AiResearch
Fuel Cells	General Electric
Cryogenic Storage System	AiResearch
Attitude Display Group	Lear, Inc.

TABLE 6–II.—*Gemini Spacecraft Controls*—Continued

MAJOR SUBCONTRACTORS—Continued	
Horizon Sensors	Advanced Technology Laboratories
Digital Command System	Motorola
Telemetry System	Electro Mechanical Research, Inc.
Recovery Parachute	Northrop/Ventura
ASSOCIATE CONTRACTOR:	
Paraglider	North American Aviation

PROJECT APOLLO

At the time that Apollo mission objectives were extended to include a lunar landing, three modes for lunar landing were considered (fig. 6–5). These modes were the direct ascent mode,

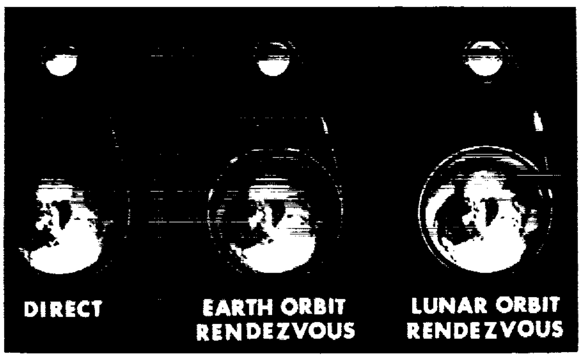

FIGURE 6–5.—Project Apollo lunar landing flight techniques.

the earth orbit rendezvous mode, and the lunar orbit rendezvous mode. After an intensive series of design and tradeoff studies, the lunar orbit rendezvous mode was selected (fig. 6–6).

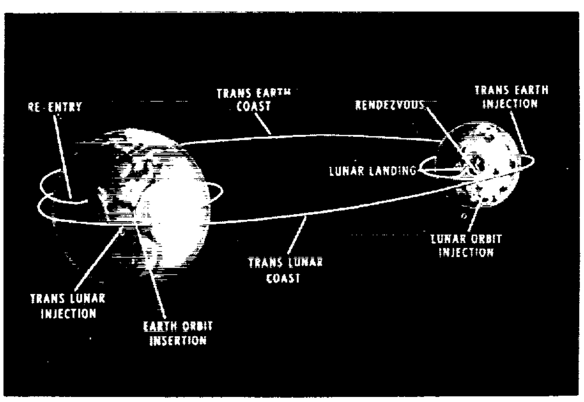

FIGURE 6–6.—Lunar orbit rendezvous.

In the lunar orbit rendezvous mode, a Saturn V launches the Apollo spacecraft into a parking orbit around the earth. Next, the third stage of the Saturn V, the S–IVB stage, injects the spacecraft into a lunar trajectory. Approximately 2½ days later, in the vicinity of the moon, spacecraft propulsipn establishes a lunar orbit. From lunar orbit the lunar excursion module descends to the lunar surface. After a day or two on the moon, the lunar excursion module is launched from the lunar surface and performs a rendezvous with the command and service modules which have remained in lunar orbit. Spacecraft propulsion is again used to inject the command and service module into a transearth trajectory. The service module is then jettisoned. Finally, the Apollo command module reenters the earth's atmosphere and performs a controlled parachute landing at a preselected site.

The Apollo spacecraft is composed of three separate modules, each designed to fulfill specific mission requirements (fig. 6–7). The

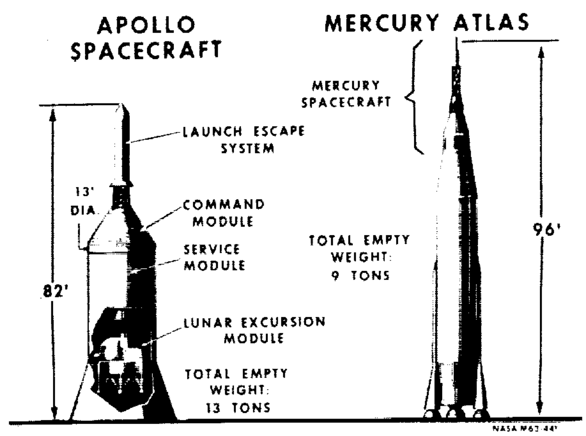

FIGURE 6–7.—Comparison of Apollo and Mercury spacecraft.

command module houses a three-man crew, serves as a control center for spacecraft operations, and is designed to reenter the earth's atmosphere safely at a velocity of about 25,000 miles per hour upon return from the moon. The service module houses many of the spacecraft support systems, and a major propulsion system for mission abort, midcourse correction, and in-

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jection into a lunar orbit. The lunar excursion module is a special purpose shuttle, or space ferry, for the two men making the lunar landing. It contains the necessary systems for descending from lunar orbit, performing the lunar landing and takeoff, and accomplishing the lunar orbit rendezvous with the command and service modules.

The three modules, together with the launch escape system, are over 80 feet tall. A comparison of the spacecraft with Project Mercury hardware shows that the Apollo spacecraft is nearly as big as the Mercury spacecraft and the Atlas launch vehicle together. The empty weight of the Apollo spacecraft is nearly one and one-half times the empty weight of the total Mercury-Atlas combination.

The Apollo command and service modules are being developed by the Space and Information Systems Division of North American Aviation, Inc., the lunar excursion module by Grumman Aircraft Engineering Corp., and the guidance and navigation system by the Massachusetts Institute of Technology and a team of industrial support contractors. All the major subcontractors for the command and service modules and for the guidance and navigation system have been selected (table 6–III). Grumman is currently in the process of selecting its team of subcontractors for the lunar excursion module.

TABLE 6–III.—*Apollo Spacecraft Contracts*

COMMAND AND SERVICE MODULES PRIME CONTRACTOR	North American Aviation, Inc.
ASSOCIATE CONTRACTORS:	
Guidance and Navigation System	MIT
Inertial Platform	A.C. Spark Plug
Computer	Raytheon Co.
Optical System	Kollsman
MAJOR SUBCONTRACTORS:	
Stabilization and Control System	Minneapolis-Honeywell
Reaction Control System (Command Module)	Rocketdyne Div.
Reaction Control System (Service Module)	Marquardt Corp.
Environmental Control System	AiResearch
Propulsion System	Aerojet-General
Fuel Cells	Pratt & Whitney
Cryogenic Storage System	Beech Aircraft
Communications System	Collins Radio Co.
Launch Escape System	Lockheed & Thiokol
Heat Shield	Avco
Earth Landing System	Northrop/Ventura
LUNAR EXCURSION MODULE ASSOCIATE CONTRACTOR	Grumman Aircraft Eng. Corp.
MAJOR SUBCONTRACTORS:	
Stabilization and Control	Specification being defined
Reaction Control	Marquardt Corp.
Environmental Control	Hamilton Standard
Descent Propulsion	Rocketdyne Div.
Descent Propulsion (Parallel Development)	To be selected
Ascent Propulsion	Bell Aerosystems Co.
Electrical Power	Specification being defined
Communications	Specification being defined
Instrumentation	Specification being defined
Radar	Specification being defined

ASTRONAUT TRAINING

An essential element for the success of any space flight mission is a well-trained crew. Because of the developmental nature of the Mercury, Gemini, and Apollo missions, requirements have been established that astronauts will be experienced test pilots with engineering and/or scientific education. Those selected are involved in an intensive training program which has proven successful for Project Mercury and which will be followed for the training of the astronauts for Gemini and Apollo missions. The astronauts are first given a concentrated refresher course in the basic sciences. They are then thoroughly indoctrinated in the workings of the spacecraft and launch vehicle systems and subsystems, as well as the operational procedures which are used in the conduct of space flight. They are trained in the environmental conditions that they will encounter in flight, such as acceleration profiles. To prepare them for a return to earth at other than the selected landing sites, they are trained in desert, jungle, and ocean survival techniques. They are given a thorough training in spacecraft operating procedures to be used during flight, including the use of ground-based trainers in which emergency conditions can be introduced to provide realistic training. The trainers will be used to provide the astronauts with the information they need to become thoroughly familiar with all aspects of their flight. Most of these trainers will be procured by McDonnell, North American, and Grumman (tables 6–IV and 6–V).

TABLE 6–IV.—*Gemini Training Equipment Contractors*

FLIGHT SIMULATORS	McDonnell Aircraft Corp.
Major Subcontractor (Computers)	Link
SYSTEMS TRAINERS	McDonnell Aircraft Corp.
Major Subcontractor	Burtek, Inc.
DOCKING TRAINER	McDonnell Aircraft Corp.
PART-TASK TRAINER	Manned Spacecraft Center
CENTRIFUGE COCKPIT EQUIPMENT	McDonnell Aircraft Corp.
EGRESS TRAINER	McDonnell Aircraft Corp.
MOCKUP TRAINER	McDonnell Aircraft Corp.
PARAGLIDER TRAINER	North American Aviation, Inc.

TABLE 6–V.—*Apollo Training Equipment Contracts*

COMMAND MODULE FLIGHT SIMULATORS	North American Aviation, Inc.
Major Subcontractor	Bids under evaluation
SYSTEMS TRAINERS	North American Aviation, Inc.
LEM FLIGHT SIMULATORS	Grumman Aircraft Eng. Corp.
Major Subcontractor	To be selected
FREE FLIGHT LUNAR LANDING AND TAKE-OFF TRAINERS	Bell Aerosystems Co.
DOCKING TRAINER	North American Aviation, Inc.
PART-TASK TRAINER	North American Aviation, Inc.
CENTRIFUGE COCKPIT EQUIPMENT	North American Aviation, Inc.
EGRESS TRAINER	North American Aviation, Inc.
MOCKUP TRAINER	North American Aviation, Inc.

INTEGRATED MISSION CONTROL CENTER

A most important element for the conduct of our flight operations is the Ground Operational Support System, which provides the information and capability to control flights from the ground. The central facility for this control is the Integrated Mission Control Center (IMCC) which is being built because the present Mercury Control Center is inadequate to control the more complex Gemini and Apollo missions (fig. 6–8). The IMCC will be located near Houston, Tex., at the new Clear Lake site of the Manned Spacecraft Center. The prime contractor for the IMCC is Philco Corp. Philco will be responsible for the design, implementation, maintenance, and operation of the IMCC under the direction of Manned Spacecraft Center personnel who will man the IMCC during flight operations. The IMCC

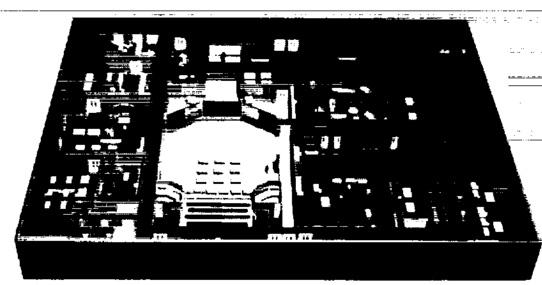

FIGURE 6–8.—Mission Control Center.

is on a very tight time schedule and must be available to control operations during the summer of 1964.

SPECIFIC PROBLEMS

The manned space flight program represents a technical challenge of a magnitude and on a time schedule almost without parallel. In the projects described, a number of specific problems have arisen for which we would welcome solutions (table 6–VI). In most cases we have an acceptable solution, but we are looking for *better* solutions. However, many of these existing solutions may have to suffice. Our time scales may just be too short to permit developmental changes in Gemini, or to permit major design changes in Apollo. Nevertheless, technical improvements in all these areas, if not on a time scale that allows their use in Gemini and Apollo, will certainly contribute to follow-on manned space projects.

TABLE 6–VI.—*Technical Improvements Needed*

Electronic:
- Lower weight power supplies
- Communications during reentry
- Speech compression techniques
- Microminiaturized equipment and bioinstrumentation
- Smaller and more reliable tape recorders

Thermal:
- Heat exchangers and insulating materials
- Reliable high temperature (5,000° R) sensors
- Surface coatings for space suits and spacecraft
- Techniques for cooling electronic equipment in space
- Ablative materials for rocket nozzles

Structural:
- Impact and vibration attenuation systems
- Higher elasticity with no degradation in strength or weight
- Welding techniques to reduce spacecraft leak rates

Personal equipment:
- Nonleaking pressure-sealing zippers and rotating suit disconnects
- Pressure-compensating joints for pressure suits
- Methods of increasing extravehicular maneuverability

Other:
- Practical space equipment maintenance techniques
- Better land recovery systems
- More reliable pyrotechnic time delay devices

ORGANIZATION

The Manned Spacecraft Center at Houston, Tex., has the direct management and contracting responsibility for the projects discussed (fig. 6–9). Technical direction of our major projects is concentrated in a number of Project Offices. The Mercury Project Office, headed by Mr. Kenneth Kleinknecht, exercises technical direction over the Mercury Project. The Gemini Project Office is headed by Mr. James Chamberlin. The Apollo Project Office, headed by Mr. Charles Frick, has technical control over the Apollo spacecraft development effort. Finally, the GOSS Project Office, headed by Mr. Paul Vavra, will direct development of the new Integrated Mission Control Center. Requirements for astronaut training equipment are generated by the Flight Crew Operations Division, headed by Mr. Warren North. Astronaut personal equipment, such as space suits, is the responsibility of the Crew Systems Division, headed by Dr. Stanley White. The manned spacecraft technology effort, which includes the development of improved subsystems and components, is the responsibility of the Assistant Director for Engineering and Developmentment, Mr. Max Faget.

Procurement and administration of Manned Spacecraft Center contracts is the responsibility of the Procurement and Contracts Division, headed by Mr. Dave Lang.

CONCLUDING REMARKS

Major accomplishments have been made in the area of spacecraft and flight missions since the first NASA-Industry Program Plans Conference in July 1960.

The goals of Project Mercury have been achieved, the Gemini and Apollo projects are now well underway, and all significant procurement actions have been completed.

In the near future, no additional major contracts are expected in this area. Such procurement must await further definitions of program requirements beyond Project Apollo.

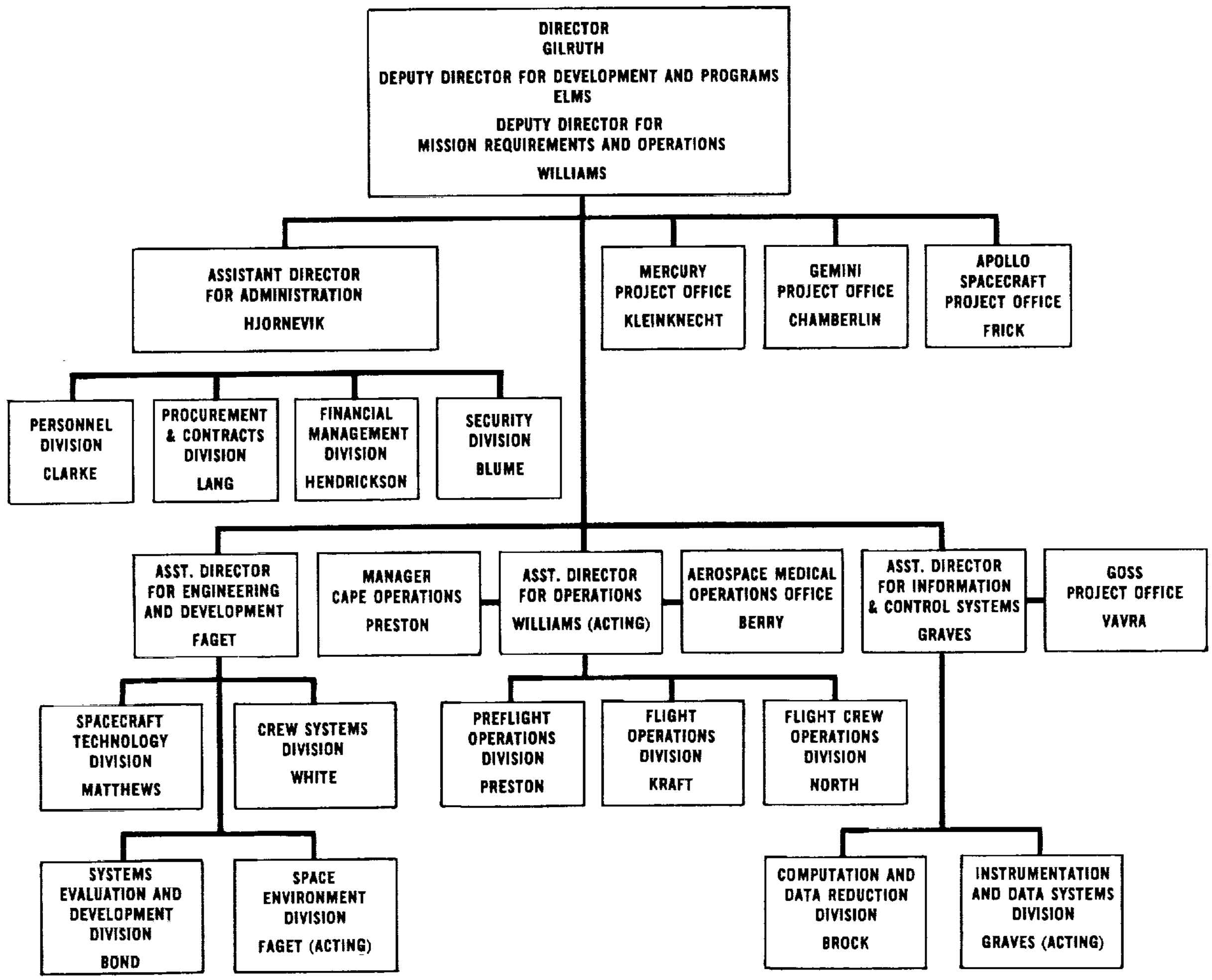

FIGURE 6–9.—Organization of Manned Spacecraft Center.

7 Launch Vehicles and Propulsion

MILTON W. ROSEN
Director, Large Launch Vehicles and Propulsion, Office of Manned Space Flight

The organization of the Office of Launch Vehicles and Propulsion and its relation to the Director, Office of Manned Space Flight, is shown in figure 7–1. The office has three Assistant Directors: one for Launch Vehicles, one for Propulsion, and one for Launch Operations. The Assistant Directors provide technical and program support.

Figure 7–2 shows the relationship of this office to NASA centers concerned with launch vehicles and propulsion. These centers are the best source of information on launch vehicles and propulsion systems, components, and contracts. The center for launch vehicles is the Marshall Space Flight Center in Huntsville, Ala. The first point of contact at Marshall should be the Procurement and Contracts Office. The Lewis Research Center in Cleveland, Ohio, is involved in propulsion development. Those interested in general information on Lewis projects should contact the Public Affairs Office; for specific components the Procurement and Supply Office should be contacted.

The third center is the Launch Operations

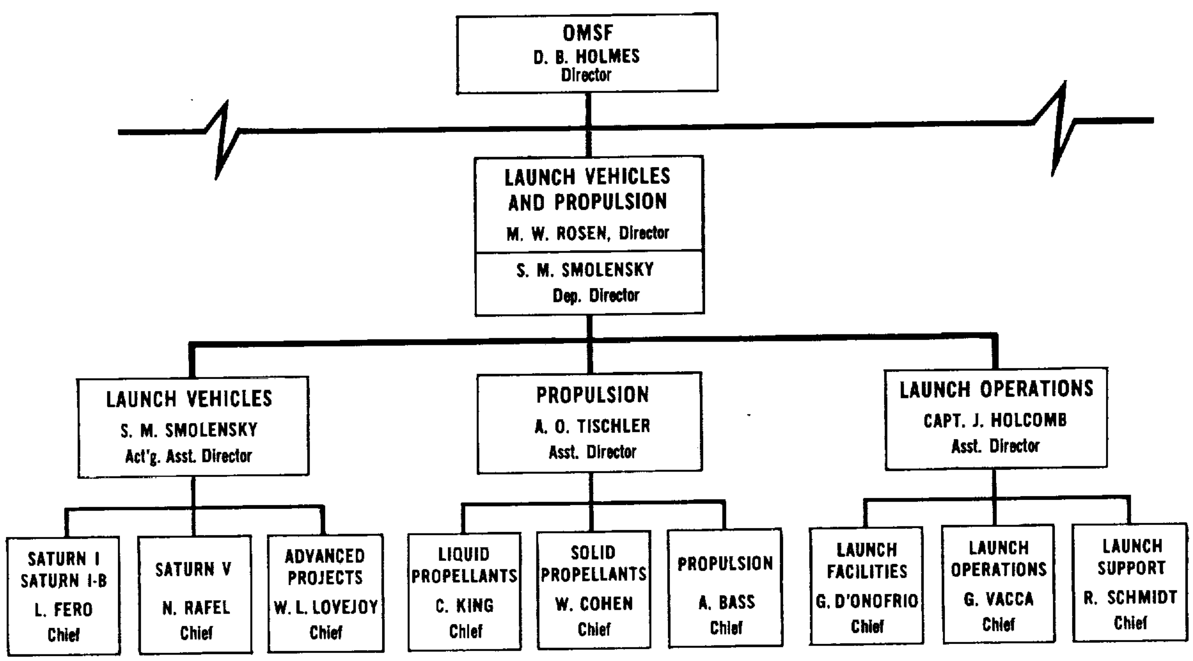

FIGURE 7–1.—Organization of Office of Launch Vehicles and Propulsion, OMSF.

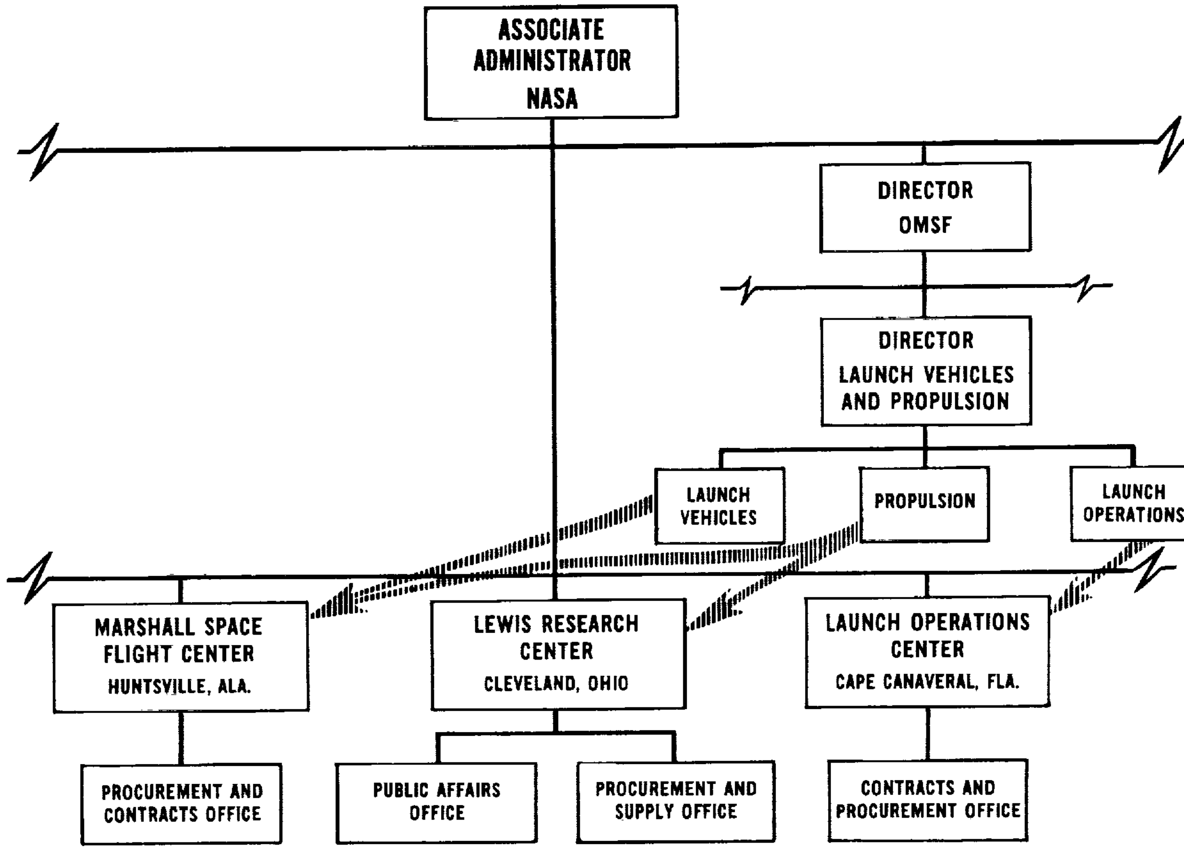

FIGURE 7-2.—Relationship of Office of Launch Vehicles and Propulsion, OMSF, to Centers.

Center (LOC) at Cocoa Beach, Fla., our principal launch site. The Contracts and Procurement Office at LOC is the source of information.

PROGRAM FOR MANNED FLIGHT

Three large launch vehicles support manned flight to the moon (figure 7-3). These are the Saturn I, the Saturn IB, and the Saturn V in the order in which they become available.

Saturn I

Saturn I (fig. 7-4), the first of the family, is a two-stage vehicle which can place 11 tons of payload in a low earth orbit. It has achieved

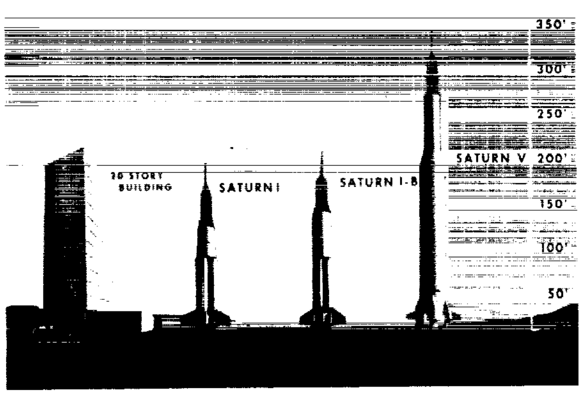

FIGURE 7-3.—Apollo launch vehicles.

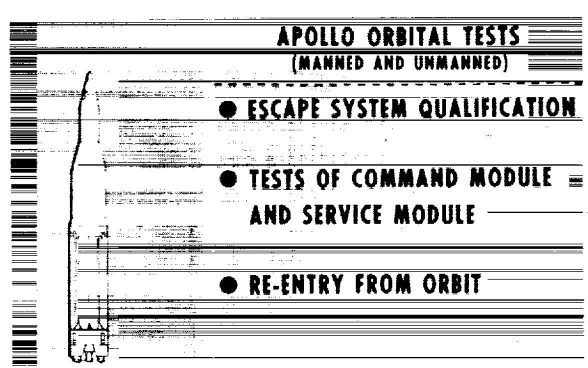

FIGURE 7-4.—Saturn I, missions.

all test objectives in its first three flights, one in 1961 and the other two in 1962. Saturn I will be used to flight test the Apollo spacecraft in earth orbit. The first stage of Saturn I (fig. 7-5), the S-I, was designed by the Marshall Space Flight Center (MSFC) and uses a cluster of propellant tanks and engines. The eight H-1 engines burn kerosene and liquid oxygen to develop a total thrust of 1.5 million pounds. Excellent reliability has been achieved with these engines because the design was derived from engines first used in Atlas, Thor, and Jupiter ballistic missiles. These engines are built by the Rockeydyne Division of North American Aviation. The first eight S-I stages have been and are being built by MSFC. Later S-I stages will be produced by the Chrysler Corp. at the Government-owned Michoud plant in New Orleans. Because of the very large size of the stage—it stands 81 feet high and has a diameter of 21.4 feet—it will be transported by barge from the Michoud plant to Cape Canaveral.

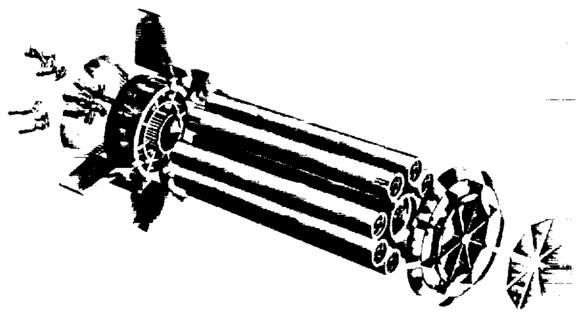

FIGURE 7-5.—S-I stage of Saturn I.

The second stage of the Saturn I vehicle burns liquid hydrogen and liquid oxygen and is being developed by the Douglas Aircraft Co. (fig. 7-6). This stage, designated S-IV, uses a cluster of six Pratt & Whitney A-3 engines, each of which develops 15,000 pounds of thrust, for a total of 90,000 pounds. The first full-duration firing of the A-3 engine cluster occurred in January 1963 when the "Battleship" configuration was fired for 468 seconds. The stage is fabricated with a common bulkhead between the liquid oxygen and liquid hydrogen tanks. Internal insulation in the liquid hydrogen tank is a unique design feature of the S-IV stage.

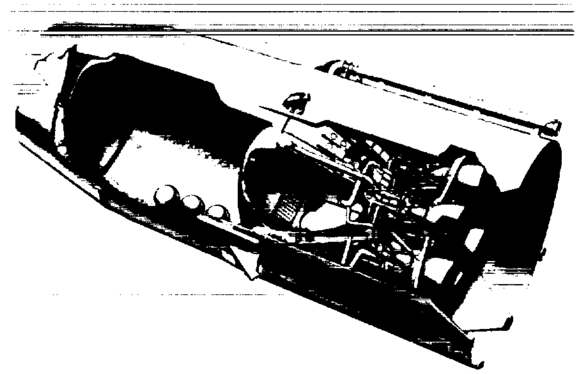

FIGURE 7-6.—S-IV stage of Saturn.

Saturn IB

The Saturn IB (fig. 7-7) is being developed in order to provide a vehicle capable of flight testing the entire Apollo spacecraft in earth orbit. This vehicle uses the S-I Block II stage of the Saturn I vehicle and the S-IVB escape stage being developed for Saturn V (fig. 7-8). The S-IVB stage uses the same structural design principles as the S-IV stage, that is, a common bulkhead and internal insulation, but has a higher propellant loading and develops 200,000 pounds of thrust from a single Rocketdyne J-2 engine which burns liquid hydrogen and liquid oxygen.

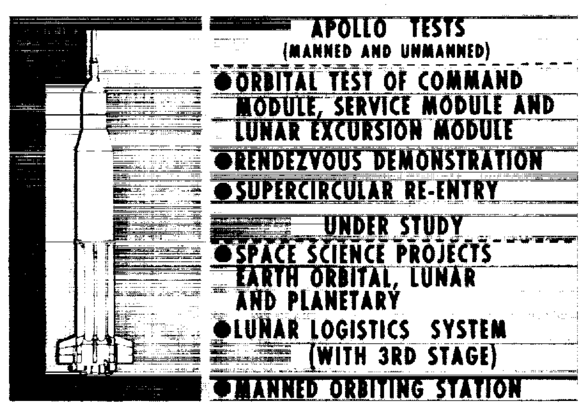

FIGURE 7-7.—Saturn IB, missions.

The Saturn IB vehicle will place 16 tons of payload in near earth orbits. This is sufficient to carry the entire Apollo payload (command module, service module, and lunar excursion module) for earth orbital testing and rendezvous testing but with only a partial fuel load in the spacecraft.

FIGURE 7-8.—S-IVB stage.

The Saturn IB vehicle will also test supercircular reentry of the Apollo command module to simulate the higher heating problems of reentry from outer space.

Saturn V

The Saturn V (fig. 7-9) will provide a launch vehicle with sufficient payload capability to perform manned circumlunar, lunar orbit, and

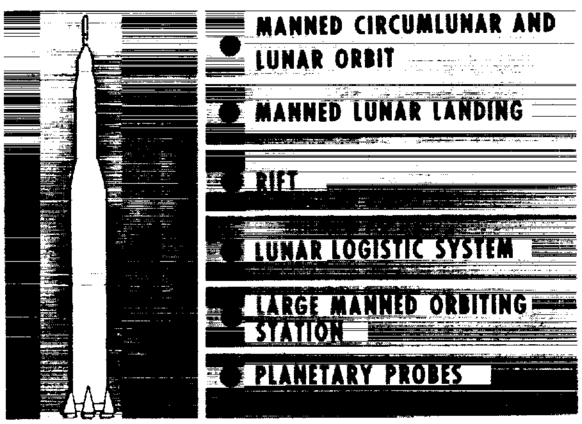

FIGURE 7-9.—Saturn V, missions.

lunar landing missions with the Apollo spacecraft. The first launch, scheduled for calendar year 1966, will be conducted at the Atlantic Missile Range at Cape Canaveral, Fla. The Saturn V characteristics are shown in figure 7-10.

The first or booster stage, S-IC, will be 138 feet long and 33 feet in diameter. It will have a dry weight of almost 150 tons and a propellant capacity of 2,200 tons. The S-IC stage (fig. 7-11) has five Rocketdyne F-1 engines arranged

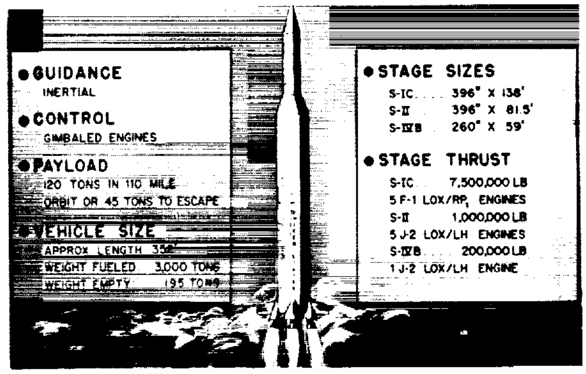

FIGURE 7-10.—Saturn V characteristics.

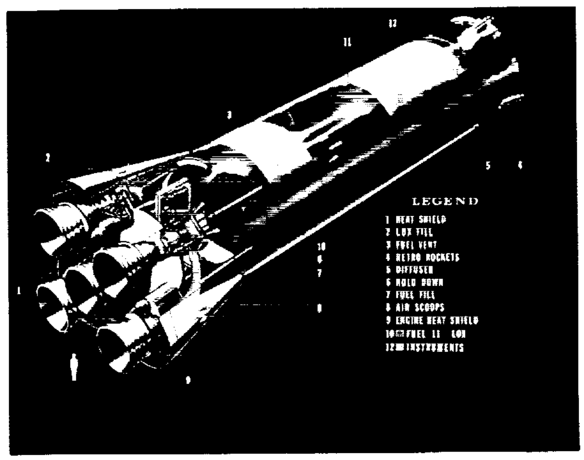

FIGURE 7-11.—S-IC stage.

in a square pattern with the outside four gimbaled and the center engine fixed. Each engine provides 1,500,000 pounds of thrust for a total of 7,500,000 pounds.

The Boeing Co., Aero-Space Division, was selected as the first stage contractor and awarded a contract in February 1962, leading to the design, development, and production of the S-IC stage.

The second stage, the S-II (fig. 7-12), will be 82 feet long and 33 feet in diameter. It will have a dry weight of 36 tons and a propellant capacity of 465 tons. Five Rocketdyne J-2 engines will provide a total thrust of 1 million pounds. The propellants will be liquid oxygen and liquid hydrogen. As in the first stage, the outer four engines are gimbaled and the center engine is fixed.

North American Aviation, Space and Information Division, was selected as the second-stage contractor and was awarded an initial

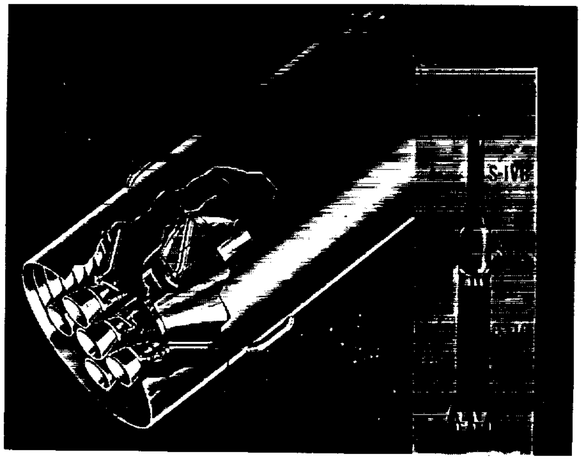

FIGURE 7-12.—Cutaway view of S-II.

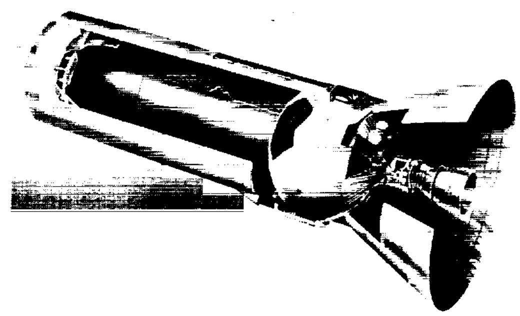

FIGURE 7-13.—S-IVB stage for Saturn V.

contract in October 1961. The stage will be assembled at a new plant now under construction at Seal Beach, Calif.

The third stage, the S-IVB (fig. 7-13), will be 60 feet long and 23 feet in diameter. The dry weight of the S-IVB stage will be 10 tons and it will have a propellant capacity of 115 tons. One J-2 engine will provide a thrust of 200,000 pounds in flight.

Douglas Aircraft Co. was selected in December 1961 as the prime contractor for the S-IVB stage. Manufacturing and assembly will be done at a new plant in Huntington Beach, Calif.

Engines

The engines currently in use or under development for the vehicles just described are shown in table 7-I. The five principle engines are the H-1, F-1, and J-2 produced by Rocketdyne; the A-3 built by Pratt & Whitney and the M-1 under development at Aerojet. Table 7-I also indicates the application, contractor, and status of the programs at this time.

TABLE 7-I.—*Propulsion*

Engines	Application	Contractor	Status
H-1	S-1 stage for Saturn I and IB	Rocketdyne (NAA)	Flight test.
F-1	S-IC stage for Saturn V	Rocketdyne (NAA)	Under development.
J-2	S-IVB stage for Saturn IB and V, and S-II stage for Saturn V.	Rocketdyne (NAA)	Under development.
RL-10	S-IV stage for Saturn I and Centaur	Pratt & Whitney (UAC)	Ready for flight test.
M-1	Nova second stage	Aerojet	Starting development.

Launch Facilities

The launch facilities for the Saturn class vehicles at Cape Canaveral are in various stages of operation, construction, and design. Complex 34 (fig. 7-14) is operational and has launched three Saturn I vehicles. Complex 37 (fig. 7-15) is under construction and will launch the fifth Saturn next summer. These two complexes, although much larger, are not much different in concept from launch facilities for Atlas, Jupiter, or Thor missiles. Saturn V, however, has required a new approach to launch operations. A series of artists drawings show the method adopted for transport, assembly and checkout, and launch. Figure 7-16 shows the Vertical Assembly Building where the stages will be checked and assembled in a vertical position. Figure 7-17 is a view of the launch vehicle inside the Vertical Assembly Building on the crawler which transports it to the launch pad. Figure 7-18 is a view of the launch pad with the servicing tower and launch vehicle lowered onto its concrete pads.

FIGURE 7-14.—Saturn Complex No. 34.

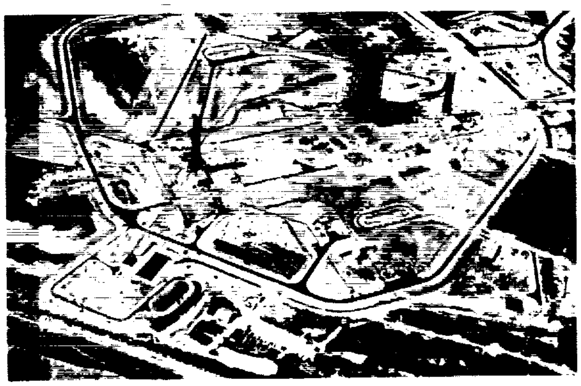

FIGURE 7-15.—Launch Complex No. 37.

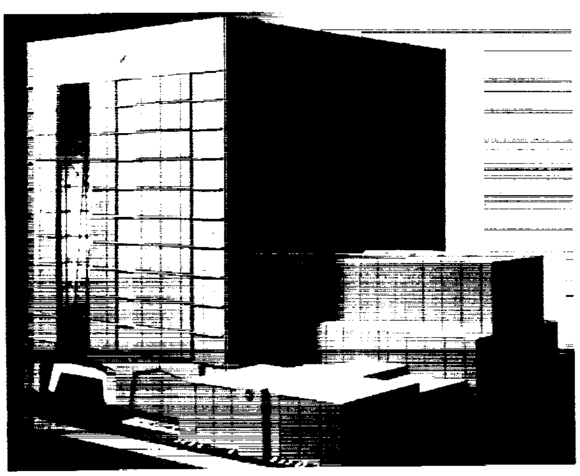

FIGURE 7-16.—Model of Vertical Assembly Building.

Support Technology

Another significant part of our effort is the Launch Vehicle Supporting Technology program. Its purposes are to solve technical problems faced in launch vehicles that are now being designed; to support design, development, and

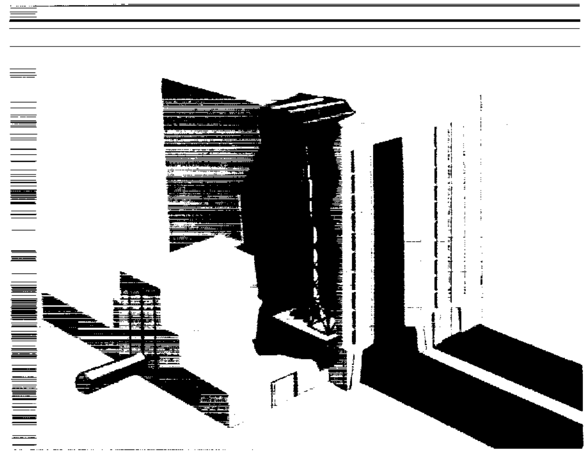

FIGURE 7-17.—Launch vehicle on crawler inside Vertical Assembly Building.

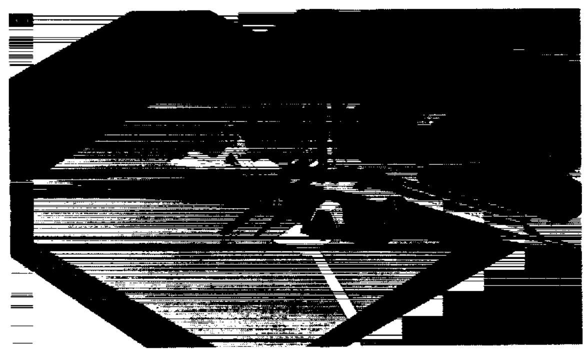

FIGURE 7-18.—Launcher umbilical tower on pad.

manufacturing of future launch vehicles; and to study advanced design concepts and advanced vehicle systems for application to space missions. Such an effort is needed to achieve quickly the highly payload capabilities required for mission objectives of national urgency, such as Apollo, and to meet the needs of the national space program for the next decade. These latter requirements will demand greater economy and compatability.

Launch Vehicle Supporting Technology tasks and studies cover many areas of endeavor and range, from a few thousand dollars to about ½ million dollars each. A partial list of technology tasks are as follows:

- Meteoroid shield studies
- Theory and design of flanges and flange connections
- Study of the response of liquids in missile containers
- Hydrostatic forming
- Quality evaluation of thick welds

Leak detection technique improvement
Multicell tank manufacturing technology
Application of dielectric materials for use at cryogenic temperatures
Development program to improve digital encoder accuracy and sensitivity
Honeycomb bulkhead fabrication technology
Low-temperature studies

As mentioned, they are in support of current launch vehicle programs and in all instances relate to known or anticipated problems.

The meteoroid shield studies are for the purpose of protecting vehicles from damage during their missions in space.

The design of flanges and flange connections requires bolstering in the plastic and elastic range so that we can obtain a complete stress and deflection picture of connections used on Saturn V.

The study of the response of liquids in missile containers will allow us to give a dependable prediction of the behavior of liquid propellants in large launch vehicles.

Through the hydrostatic forming task we are hopeful of reducing the tooling costs on the metal parts of large launch vehicles such as propellant containers and closure bulkheads.

As part of a continuing effort to improve our quality control procedures, we are investigating the feasibility of using eddy current techniques in the evaluation of thick welds.

The current methods used for leak detection are relatively inaccurate, too time consuming, lack operational ease, and do not lend themselves to remote or automatic operation.

The multicell tank manufacturing technology task is to develop the technique of automatic out-of-position welding of aluminum-alloy plates for 30-foot and larger diameters. This technique has been demonstrated on a laboratory basis.

The development of dielectric materials which are subject to mechanical vibrations at cryogenic temperature is important to increasing the reliability and characteristics of cabling for launch vehicles.

The development to improve digital encoders is for the purpose of providing an absolute azimuth position digital readout of inertial platform azimuth to an accuracy of ±5 seconds of arc.

It was mentioned that the S–IV and S–IVB vehicle stages use the common bulkhead technique for propellant separation. Although this method succeeds in terms of lower weight and higher stiffness, it is more difficult to manufacture than conventional tankage. The common bulkhead employs a sandwich method of construction in which a fiber-glass material in the form of a honeycomb is sandwiched between two spherically shaped sheets of aluminum. If the bonding of the honeycomb to the aluminum skin is without flaw, a panel of high strength and low weight results. Although the manufacture of these bulkheads is, at present, a tedious process, it is hoped that improved methods of fabrication can be developed not only to reduce cost but also to assure greater reliability of the bulkhead.

The low-temperature task can best be illustrated by a problem experienced in this area. The case in point is an umbilical (fig. 7–19)

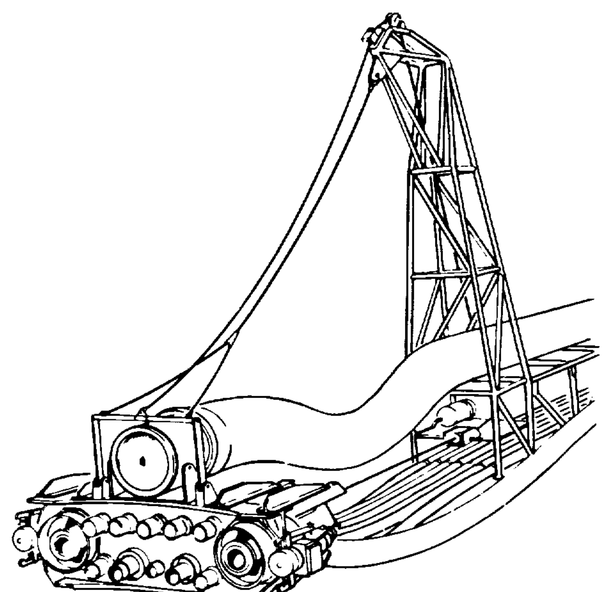

FIGURE 7–19.—Umbilical connector.

designed with four methods of disconnect—three redundant (one automatic hydraulic device and two mechanical force devices). The prime automatic method is pneumatic actuated by a monitoring signal. In the event the pneumatic device fails, a hydraulic system is actuated. Third, a lanyard is attached to the umbilical which mechanically actuates cam releases at vehicle lift-off. The last backup device is a set of pins which are sheared by the force of the launch vehicle as it leaves the pad. In the case being described, the pneumatic failed, the hydraulic failed, the lanyard made final separation but in so doing destroyed the umbilical. Part of this problem was attributed to the low temperatures of the propellant flowing through the umbilical. A torque-tube arrangement (fig. 7–20) has been ap-

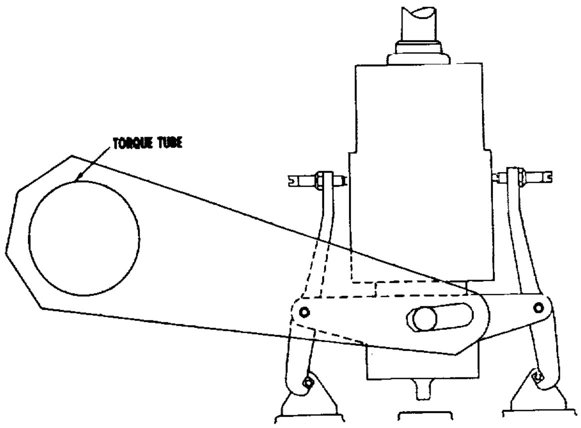

FIGURE 7–20.—Modified umbilical disconnect.

plied to prevent cocking of the connector when binding occurs on the hydrogen coupling. This problem is given as an example because we have been working with umbilical connectors for more than a decade. It points out that in the rapid pace of space technology no piece of hardware can be considered usable until tests designed to determine reliability are performed under environmental operating conditions.

The reliability of vehicle support equipment must be continually upgraded and better techniques and procedures applied. One consideration in the improvement of the reliability of launch instrumentation is the application of solid-state switching devices. Many problems at the launch site result from stray currents and radio interference. Better methods are required for recognizing these problems. Cable and connector development is an area in which we are looking for improvements. Conventional round wire cables and connectors are frequently unsatisfactory in applications where flexibility, small size, light weight, and reliability are desired. The use of flat printed cables and related connectors promises to provide an improvement in these characteristics as well as an overall cost reduction. Sample cables have been tested, for example, at temperatures from −65° C to 100° C without failure but efforts will be made to increase this upper temperature limit to 250° C. High-frequency coaxial applications and performance at altitudes of 10^{-7} to 10^{-9} millimeters of Hg are also being investigated.

Some of the problems concerned with propellant storage and transfer are listed as follows:

Subcooling systems and densifying techniques for liquid hydrogen
Better pumping systems for high-pressure gas
Propellant transfer in space
Leak detection in space

Subcooling of liquid hydrogen from its normal boiling point of 20° K down to or near the freezing point at about 14° K is required to reduce the boiloff of hydrogen when servicing into the launch vehicle tanks and while the vehicle is being launched into orbit. Successful densifying of liquid hydrogen by partial freezing or other techniques will permit a reduction in tank weight and size, possibly permit the inclusion of metal additives, and contribute to the heat-sink effect of subcooled hydrogen.

The ground servicing equipment presently used for pumping high-pressure gas into the launch vehicle is difficult to maintain and requires great diligence to avoid contamination by oil and other matter which could come in contact with the liquid oxygen or the fuel. Therefore, better means are required for transferring the high-pressure gas.

Orbital rendezvous will frequently require the transfer of propellant under the weightless condition of space. This requires some means of positive expulsion of the propellant or some new technique to effect the transfer.

Also of concern in the temporary storage and utilization of propellants in space is the need for determining small leaks, particularly leaks out of the system and into atmosphereless space. Present ground techniques usually depend on the earth's atmosphere and are not applicable to systems in space. In addition, the accessibility is limited.

Launch instrumentation is used to provide data on which development of the ground support equipment and the vehicle are based, as well as to check out a completely developed system. The increased complexity and number of components involved in large space vehicles require improved instrumentation. The development and increased usage of digital instrumentation techniques and the subsequent development of automatic checkout techniques has required further improvement and application of digital systems. A primary requirement exists for digital transducers to measure pressure, temperature, and so forth. The automatic checkout systems also require improvement. Acoustic measuring devices with a much greater frequency range are needed for environmental determination in the development of launch vehicles and launch equipment. Some of the equipment and facilities are:

- Vertical transport of large launch vehicles
- Handling, erection, and clustering of large solid boosters
- Launch pad flame deflectors for large solid boosters

8 Program Plans

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Deputy Director (Systems),
Office of Manned Space Flight

Within the Office of Manned Space Flight, the Office of Systems provides the central system engineering team required to establish the overall system concept and to provide continuing technical review of the ongoing programs. In addition, the Office of Systems provides the focus for long-range planning and studies for future manned space flight programs, and coordinates such activities in the centers.

We have been building the organization during the last year and now have on board approximately half of the planned total complement of 125 members of the technical staff.

In February 1962 NASA requested the assistance of the American Telephone & Telegraph Co. in the system engineering effort for the manned space program. AT&T responded to this request by forming Bellcomm, Inc., in March. The total technical staff at Bellcomm is expected to be 175 people by the end of this year. Almost half of this number are now on board. The support provided by Bellcomm satisfies our need for continuous technical support. However, much special study activity must still be contracted to industry, either directly from the Office of Systems, or through the centers.

The role played by the Office of Systems in the ongoing projects is similar to a system engineering function as it has developed on most major programs. We are responsible for technical monitoring and coordination of the R&D efforts to assure that the system as a whole remains in good engineering balance and that it will meet the mission objectives in a timely fashion. The system engineering function presently occupies a major part of our manpower. The function is performed in close cooperation with the appropriate NASA centers and through those centers to their contractors. Occasionally, need arises for specific studies which relate to the Apollo or Gemini program. Some of these studies are contracted directly from the Systems Engineering Office. Since they arise from specific requirements which develop within the program, it is difficult to predict the exact magnitude of this contracting effort. The best estimate is that it will run between $1.5 and $2 million during fiscal year 1964.

The major interest, from industry's viewpoint, is probably in the study activities which relate to future potential manned space programs. These activities are the responsibility of the System Studies Directorate and frequently require contractor participation for the execution of the studies.

In the area of future programs, it is impossible at this point in time to predict either what programs will ultimately become approved, or the schedule on which they will be implemented. It is obvious that the exploration of the moon is not the end but the beginning of man's conquest of space. We are presently carrying out planning and studies involving programs that provide direct support to the manned lunar landing program and extend the scope of lunar missions, manned earth orbital operations, and manned planetary missions. Until now, this nation has taken on almost every task in space that was feasible. As soon as the rocket power became available, we launched space satellites and space probes. The Mercury astronauts were launched into space the very first day we though it safe. The same will be true on our lunar exploration program.

Soon, however, we shall have available rocket power and advanced propulsion systems, spacecraft technology, facilities, and operational techniques that will allow us to go in many directions in space. We will be in a position to pick and choose among our possible space programs. All those mentioned are desirable, but we face the problem of cost.

The selection of the specific projects we pursue, the schedule on which they will be implemented, and the amount of national resources which are committed to them are questions for the Executive Branch, the Congress and all the American people to consider. The task in the system studies area is to provide the best definition possible of the choices available and the technical and economic data required to make intelligent decisions. As a general rule, an advanced manned space project does not spring full blown from the mind of a single individual or group. The aerospace community, recognizing the general goals of the advanced program, produces a constant stream of new ideas, new techniques, new applications, and new configurations. Feasibility studies and preliminary designs are being produced continually by groups within NASA, the DOD, and industry. It is the function of the System Studies Directorate to monitor and guide this occasionally erratic stream of ideas as it applies to advanced manned space projects. The goal is to have available, at the appropriate point in time, as much data as possible to provide the basis for decision. At the present time, the studies of advanced manned space flight projects fall into four major areas: the Lunar Logistic System, the Lunar Base, Manned Earth Orbiting Space Stations, and Manned Planetary Missions.

The Lunar Logistic System, as the name implies, would be capable of delivering payloads. to the moon in support of the Apollo landings. Although it is not yet certain that this capability will be worth the money and manpower required to develop it, we can conceive of three potential uses of such a system:

(1) Site verification and preparation
(2) Increased exploration capability
   (a) Greater mobility
   (b) Longer stay time
   (c) More scientific equipment
(3) Logistic buildup for the Lunar Base

Present knowledge of such lunar surface characteristics as bearing strength, surface roughness, and slope is not adequate. Although considerable improvement in this situation is expected from the Ranger and Surveyor projects, it is not certain that sufficient information will be available from these unmanned probes prior to the first Apollo landing. We are conducting studies to determine whether a significant improvement in our confidence in a successful landing could be obtained through the use of a larger payload. Such a payload might include a roving vehicle capable of measuring bearing strengths and other soil mechanics parameters throughout the potential landing site, and an RF landing beacon to assure a landing within the area which has been measured. Reconnaissance payloads and surface probes which might be carried on Apollo missions will also be studied.

Once the initial landings have been made, increases in exploration capability might be obtained through the use of a lunar surface vehicle to provide greater mobility to the explorers. The required nominal range appears to be 200 miles, but is very sensitive to surface conditions. An increase in the duration of an Apollo landing can be obtained for around 100 pounds per day, including oxygen, water, food, and power, plus packaging for these items. The command module, remaining in lunar orbit, limits this sort of extension to roughly 7 days.

The Landing Excursion Module (LEM) can carry about 215 pounds of scientific equipment to the lunar surface and can return about 80 pounds of samples, exposed film, and records to the orbiting command module. The amount of scientific equipment available on the surface could be usefully increased up to a maximum of 1,000 pounds. Beyond this point, it is doubtful whether the two crew members could make use of additional equipment within the short time available. The scientific value achieved per pound of additional equipment is not a linear function, even below this 1,000-pound maximum, and seems, in fact, to approach it asymptotically. Clearly, a large element of judgment has to be included in this area.

Our studies to date indicate that a semipermanent lunar base would require extensive logistic support, both for initial buildup and for continuing operation. For example, a 12-man base would require around 240,000 pounds initially, plus 8,500 pounds per month of operation. Clearly, the present Apollo lunar orbit rendezvous (LOR) configuration alone could not handle the volume of material required for such a base.

It should be emphasized that this discussion concerns things which *might* be done *if* we were to adopt a lunar logistics system program. We have been engaged in an extensive study program over the past few months to explore the feasibility of such a system, its costs, its effect on other portions of the program, and similar factors. Portions of the problem have been explored by NASA and Bellcomm personnel in Washington, at the Marshall Space Flight Center, and at the Manned Spacecraft Center. In addition, we have funded studies by industry for a total of $350,000.

Two possible configurations have emerged from the study effort.

The first possibility is to use the Apollo configuration, with the LEM ascent stage replaced by a cargo platform. This approach would involve a manned flight into lunar orbit and an unmanned landing of the cargo carrier. We call this the LEM truck technique. It would provide between 5,000 and 6,500 pounds of landed payload.

The second possible configuration is a logistics spacecraft delivered to the moon by the Saturn V. The spacecraft would be a two-stage device, using the same stage for deboost into lunar orbit as that used for the third stage of the Saturn IB configuration. Descent and landing would be accomplished with a second hydrogen-oxygen stage and the net landed payload would be 25,000 to 30,000 pounds.

Each of the configurations is characterized by its own set of advantages and disadvantages. The LEM truck technique requires no new stages and, in general, is the least expensive program involving a minimum of interference with the Apollo program. The Saturn V offers the maximum payload potential, but would be more expensive.

Logistics system studies in fiscal year 1963 will total around $800,000. Additional studies of advanced concepts will be continued during fiscal year 1964 for about $400,000 more.

The next area of discussion is the lunar base. For our purposes, we define a lunar base as any project which would permit man to remain on the lunar surface for periods longer than 2 weeks. Although it certainly is not obvious at this time that man will want to stay on the moon for long periods, it is apparent that our program might require this capability either for extended lunar exploration or exploitation.

It is apparent from the preceding discussion that we cannot now list a meaningful set of objectives for the lunar base program. We do talk of expanded scientific exploration of the moon, of optical and radio telescopes, of exploitation of lunar materials, and so on. But, in reality, we do not yet know whether the moon will turn out to be suitable for these purposes.

The purpose of our present program is to identify the types of bases which might be required and the equipment which would be needed for them. For example, a few contractor studies of lunar construction techniques have been initiated, and this subject will be explored more extensively during the remainder of calendar year 1963. Similarly, we will fund some studies of lunar exploration techniques and perhaps one or two studies of means for exploiting lunar materials for support of the base, depending on the availability of data from the Ranger program.

Other studies will be directed at vehicle configurations and operational concepts associated with longer lunar missions. Fiscal year 1963 totals for this area will be around $1.2 million, plus another $2 million in fiscal year 1964.

The third major area of advanced thinking is the space station effort. This title is used rather loosely to describe all projects which involve manned flights in earth orbit for durations greater than 2 weeks. In this generic sense, there have been a great many studies and preliminary designs of space stations generated by various groups. These have ranged from a relatively simple modification of the Apollo command module to provide a capability of flight durations up to about 100 days, through orbiting laboratories (both rotating and nonrotating), to elaborate facilities housing as many as 40 men. A major problem with the studies which have been done so far is that they tend to be vague concerning the purpose of the station. The greatest emphasis has been placed on demonstrating feasibility, with the result that we are faced now with an array of feasible space stations from small, inexpensive projects to very large, very expensive ones. To choose among these, we need to specify more carefully what we wish to do in the station and what value these uses may have for the NASA program and for the Nation as a whole.

In 1962, we completed a survey of potential uses for space stations and possible station configurations. We are currently trying to explore the feasibility and value of these possible uses, and to match them to the configurations.

The question of fundamental importance to the future of the manned space flight program is whether man can tolerate months or years of weightlessness and continue to perform effectively.

After reviewing the various physiological mechanisms which might cause difficulty, it appears that successful flights of about 3 months in duration would provide a reasonable level of meaningful data. That is to say, if we can demonstrate good tolerance for 3 months, we would be fairly safe in extrapolating this to a 12-month planetary mission. This extrapolation would be verified in earth orbit during the actual flight testing of the extended mission duration spacecraft.

We are studying methods of accomplishing a 3-month flight by modifying a Gemini or Apollo spacecraft to provide for longer stay times, using a Saturn-class launch vehicle to place it in orbit. A major uncertainty in this approach is whether either of these spacecraft provides sufficient room to perform the experiment. It is not enough simply to place the astronauts in orbit for 3 months and then return them to earth for medical evaluation. Many of the physiological mechanisms of interest would first reduce the man's tolerance to reentry g's, and only later affect his performance in orbit. Fairly elaborate physiological and performance monitoring would be required to detect potential failures before they have progressed to the point where the man cannot reenter safely. In all probability, for example, we will have to perform chemical analyses of blood and urine samples during the flight. One estimate of the amount of space required to provide adequate monitoring is 3,000 cubic feet, roughly eight times larger than the Apollo command module.

The primary justification for this concept is to establish man's tolerance to extended periods of weightlessness. Undoubtedly, other uses for the station will be included, not as justifications but as useful things which might be done given the existence of such a station. These secondary uses will consist primarily of scientific observations and engineering experiments related to subsystem development problems.

Contractor studies in the space station area will total about $2.5 million in fiscal year 1963 and around $2.8 million during fiscal year 1964.

We will continue to study larger, multimanned space stations capable of providing artificial gravity for more extensive missions. In addition to the concept of a space station as a "national research facility," it is likely that planetary missions will involve assembly, checkout, and launch operations performed in earth orbit. This may well involve some form of manned orbital launch facility, but our planning simply is not far enough along to comment on what sort of a space station this might be.

The last area is the planetary exploration program. We consider Mars to be the most likely choice for our first attempt at planetary exploration, since its environment appears to be less hostile than that of Venus. It is also more likely to have some form of life, and is therefore of greater scientific interest. Although consecutive launch windows from Earth to Mars are about 25 months apart, they are not equally attractive because of the eccentricity of the Martian orbit and because the 11-year solar cycle influences radiation shielding requirements. Studies completed to date indicate that we would be overly optimistic if we planned to use the 1973 launch window.

The major problem is the development schedule for solid core nuclear propulsion systems. Choosing the 1975 window would help the schedule somewhat, but would still be rather optimistic. It would appear that the windows from 1977 to 1981 are not usable because of the greater transfer energy required combined with an increase in solar activity. Thus, we may be faced with a choice between trying for the single 1975 window or not attempting a planetary landing until after 1981.

The total picture is not quite so dark as indicated. Other options available are Venus and Mars flyby or orbital missions, without landings, using the Saturn V with a nuclear third stage; another option is the development of more advanced propulsion systems rather than relying on solid core nuclear reaction schemes. Nevertheless, it is fair to indicate that we are not now certain that a manned planetary landing is feasible before the 1980's. Our major effort during this year will be an extensive study program directed at obtaining more realistic estimates of payload requirements, further studies of advanced propulsion systems, and attempts to find for sophisticated mission profiles which could reduce the propulsion requirements. A large space station is a prerequisite for the development of the planetry spacecraft.

Spacecraft and mission profile studies will total about $750,000 during fiscal year 1963 and $1.5 million in fiscal year 1964. A somewhat larger effort will be placed on launch vehicle and propulsion studies during this period.

In this paper an attempt has been made to summarize our present thinking with regard to future manned space flight projects. These range from fairly specific projects to rather vague concepts still in the early study stage. The uncertainties are disturbing. However, one of the major attractions of manned space flight is alleged to be the challenges inherent in trying to accomplish the impossible. We seem to have an ample supply of such challenges, and assistance in wrestling with them is welcome.

9 Facilities in Support of Manned Space Flight

WILLIAM E. LILLY
Director, Program Review and Resources Management, Office of Manned Space Flight

Program Review and Resources Management provides a wide range of support services for the Office of Manned Space Flight. Its three divisions, Plans and Resources, Facilities, and Program Management Support, are organized to carry out responsibilities that cover financial and business management, administration, and resources planning. A key function is the planning, administration, and management of facilities acquisition. The accelerated pace of the manned space flight effort has created urgent requirements for facilities for hardware development, fabrication, and ground testing, as well as launch sites. In fiscal years 1963 and 1964 alone, the magnitude of the facilities program for Manned Space Flight exceeds $1.1

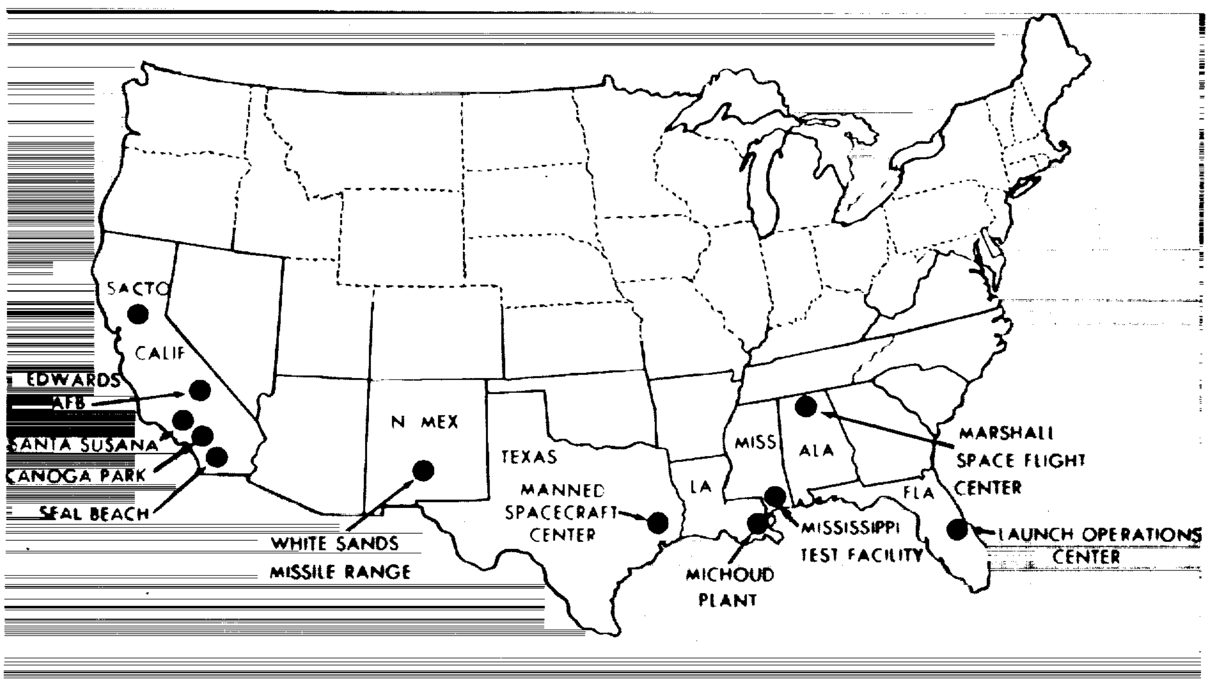


FIGURE 9–1.—Geographical location of major facilities, Manned Space Flight program.

billion. In light of these technical requirements and the leadtimes necessary for technical facilities, we are now involved in a far-reaching effort to construct well-equipped and reliable facilities.

The major locations of facilities in support of manned space flight are identified on the map in figure 9–1. Our facilities program encompasses projects at NASA Centers, Department of Defense installations, and contractor sites. A great number of facilities are required to meet the needs of the Manned Spacecraft Center in Houston, the Marshall Space Flight Center in Huntsville, the Mississippi Test Facility, the Michoud Plant in New Orleans, and the Launch Operations Center at Cape Canaveral. To complement activities at these points, we have planned or located facilities at other Government installations and contractor sites. For example, we are constructing the necessary facilities for developmental tests of the Apollo propulsion system at the White Sands Missile Range in New Mexico. On the west coast we are constructing facilities to support both stage and engine development for the Saturn launch vehicle.

These functions of development, fabrication, test, and launch that must be fused together to support the Manned Space Flight Program are portrayed in figure 9–2. Overall program

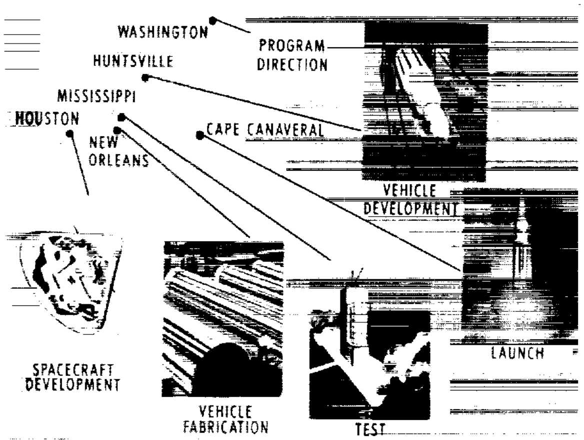


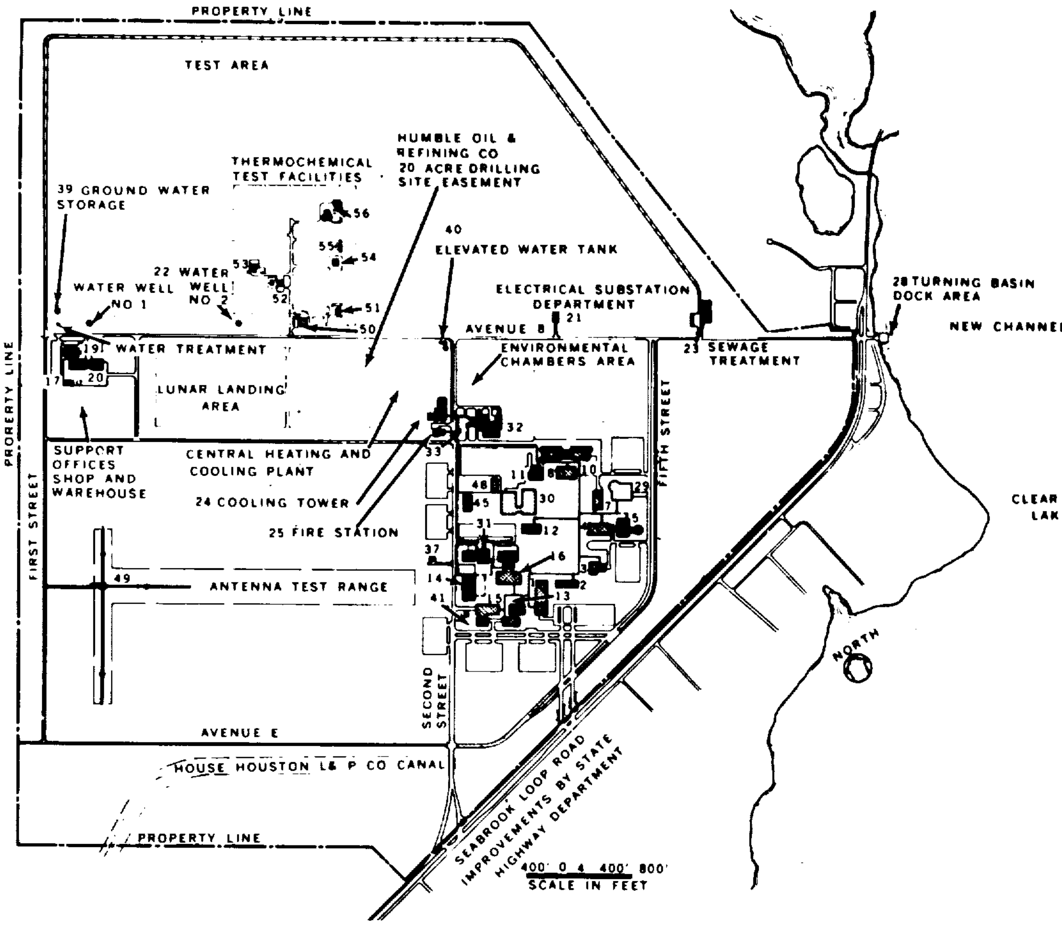
FIGURE 9–2.—Major activities, Manned Space Flight program.

management lies with the Office of Manned Space Flight. Responsibility for spacecraft development, flight crew training, and flight missions operations is focused at the Manned Spacecraft Center in Houston, Tex. Development of large launch vehicles and propulsion systems is accomplished through the Marshall Space Flight Center in Huntsville, Ala., with major fabrication and assembly of the Saturn-class booster to be conducted at the Michoud Plant, near New Orleans. The Mississippi Test Facility, situated about 35 miles from the Michoud Plant, answers the need for a nearby ground test area for vehicle stages and components. Finally, facilities at the Launch Operations Center, Cape Canaveral, will provide complexes with the rapid-launch capability that future flight schedules demand. The availability of a good water transportation system was a significant factor in selecting locations for these integrated functions. The following highlights of our facilities projects at these locations will indicate the variety of construction planned and the opportunities that are available.

We are constructing the Manned Spacecraft Center (MSC) on some 1,600 acres of land at Clear Lake, near Houston, Tex. During fiscal year 1962 we started site development and design for this new location. Occupancy of the facility will start in early 1964.

The master plan in figure 9–3 reflects the magnitude of the construction effort that is required. Since the Manned Spacecraft Center has responsibility for spacecraft development, flight crew training, and flight missions operations, highly specialized facilities, ranging from engineering buildings to experimental laboratories, are needed. The artist's conception in figure 9–4 conveys a picture of the completed center. An estimated 30 buildings and other utility installations will be erected at the Clear Lake site. In 1962, we initiated construction of major support utilities, as well as the Flight Crew Operations Building, the Life Systems Laboratory, and the Project Management Building.

Construction of the MSC Environmental Test Facility, illustrated in figure 9–5, will begin in 1963. This building will house facilities for subjecting full-size Apollo spacecraft to the stresses of simulated flight. Two simulation chambers will be built. One will be used to evaluate the complete spacecraft and spacecraft systems; the second will be used for training flight crews and developing crew environmental and survival systems. Construction of the Thermochemical Test and Flight Acceleration Facilities, which are now in design status, is scheduled to begin in 1963. The Thermochemi-



BUILDING INDEX:

1 Auditorium
2 Project Management
3 Cafeteria No. 1
4 Flight Operations Office
5 Mission Simulation and Training Facility
7 Life Systems Lab
8 Tech Services Offices
10 Tech Services Shop
11 Cafeteria No. 2
12 Central Data Office
13 Systems Evaluation Lab
14 Launch Environment and Antenna Test Facility
15 Systems Evaluation
16 Spacecraft Research Office and Lab
17 Garage
19 Support Office
20 Support Shops and Warehouse
21 Electrical Substation
22 Water Treatment
23 Sewage Treatment
24 Central Heating and Cooling Plant
25 Fire Station
28 Barge Dock
29 Flight Acceleration
30 Integrated Mission Control Center
31 Space Physics Facilities
32 Environmental Test Lab
33 Refrigeration Building
37 Source Calibration Facility
40 Elevated Water Tank
41 Gas Storage
45 Project Engineering Facility
48 Emergency Power Bldg.
49 Antenna Service Bldg.
50 Thermochemical Test Facility
51 Attitude Control Test Facility
52 Pyrotechnic Test Facility
53 Reaction Control Test Facility
54 Space Power Systems Test Facility
55 Hydrogen Storage
56 Components Test Facility

FIGURE 9-3.—Site plan, Manned Spacecraft Center.

FIGURE 9-4.—Artist's conception of Manned Spacecraft Center.

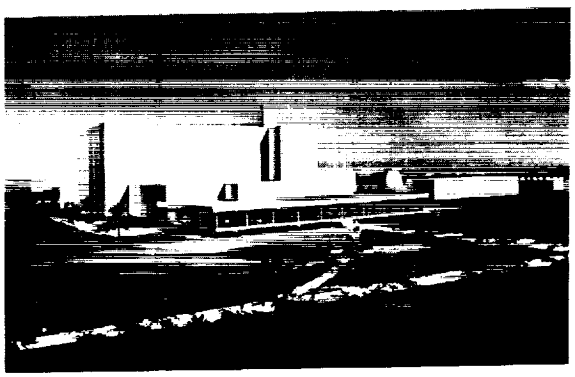


FIGURE 9-5.—Environmental Test Facility, MSC (artist's concept).

cal Facility will house specialized equipment for evaluation and development of spacecraft systems, such as attitude control, thermal control, and propulsion. The Flight Acceleration Facility will be used to familiarize the astronauts with flight conditions and will require construction of a large high-gravity centrifuge. As pointed out in paper 6, major effort will be devoted to the Integrated Mission Control Center, which will serve as the nerve center for Gemini rendezvous missions and all Apollo missions.

The Marshall Space Flight Center is already well established in the field of launch vehicle development. This center also occupies approximately 1,600 acres of land. As the marked areas on the site plan (fig. 9-6) indicate, Marshall has facilities for development, manufacture, and ground test of launch vehicles. The manufacturing facilities are concentrated at the northern end of the center; the development facilities are clustered nearby; the test area is situated in the southern portion.

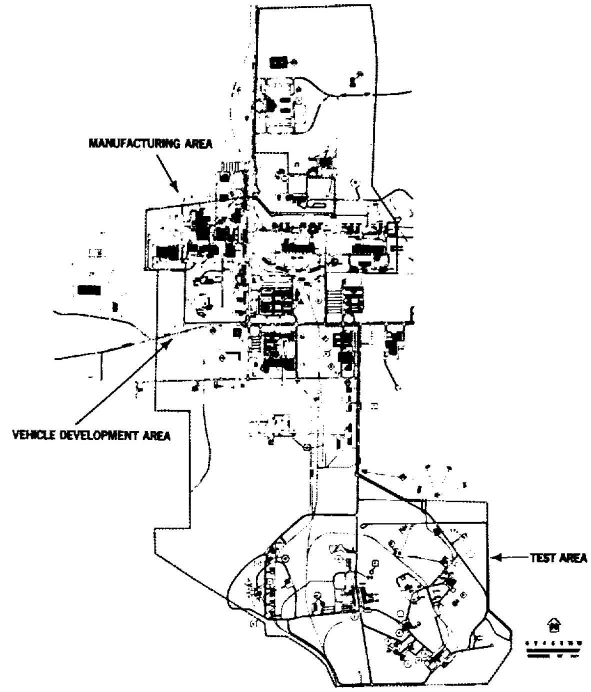


FIGURE 9-6.—Site plan for Marshall Space Flight Center.

When the pace of launch vehicle development was accelerated, it was apparent that existing facilities would have to be modified and that new facilities would have to be added. Only one static test stand, where ground testing of the first stage of the Saturn I is conducted, is available at present (fig. 9-7). To remedy this situation, we are adding a second test position to the present stand. We are planning to modernize the instrumentation and control system of the blockhouse. In addition, we are constructing a new static test stand for development of the Saturn V first stage.

In the area of vehicle fabrication, the Government-owned Michoud Plant near New Orleans is being renovated and modified for production and assembly of Saturn first stages. An aerial view of the Michoud site is shown in figure 9-8. The entire Michoud site occupies about 825 acres and the plant alone ranges over some 43 acres, all under one roof. Contractors for Saturn-class vehicles will use the facilities of the plant, under the technical and administrative direction of the Marshall Space Flight Center. The Chrysler Corp. is fabricating the first stage of the Saturn I vehicle at Michoud and The Boeing Co. will manufacture the first stage of the Saturn V there.

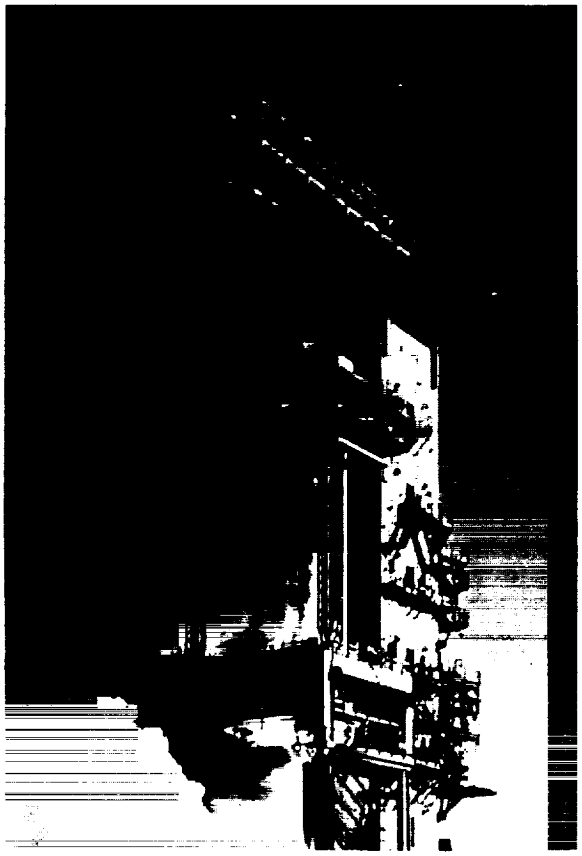


FIGURE 9-7.—Static test stand, Marshall Space Flight Center.

FIGURE 9-8.—Michoud Plant, New Orleans, La.

A new Michoud Facility, a 200-foot-high Vertical Assembly Building (VAB), is being constructed and should be completed by early 1964 (fig. 9-9). This building will be equipped to handle the assembly of the major stage components. The hydrostatic test area, which will be used for structural tests and cleaning of the fuel tanks, will be part of the Vertical Assembly Building. Other improvements required

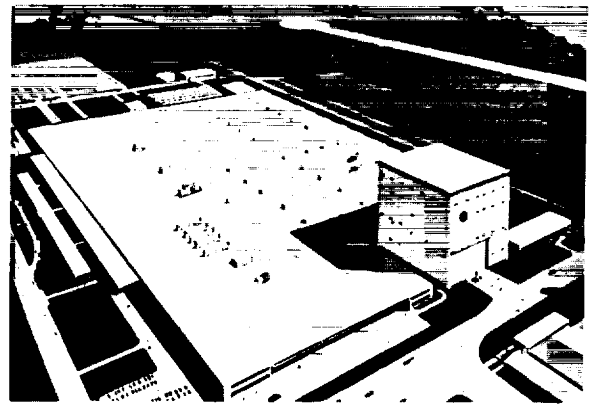


FIGURE 9-9.—Vertical Assembly Building, Michoud plant (artist's concept).

at Michoud are additions to the production facilities and construction of a supply building for vehicle components, as well as expansion of the parking facilities, erection of security fences, and rehabilitation of the roads and airstrip.

Manufacturing facilities for Saturn upper stages are being constructed on the west coast. The second stage (S-II) of the Saturn V will be assembled at Seal Beach, Calif., where NASA has acquired 35 acres from the Navy Department through a Use Agreement. An artist's conception of the Seal Beach S-II Facility, shown in the foreground of figure 9-10, illustrates the structures that will be erected. These facilities will provide for fabrication, vertical assembly, and hydrostatic and pneumatic testing of the S-II stage.

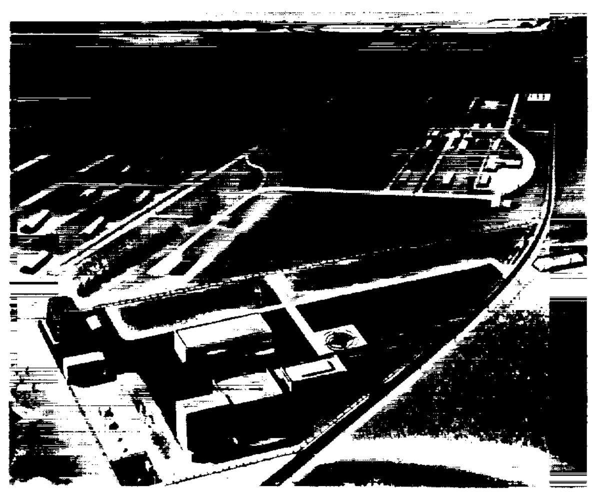


FIGURE 9-10.—Saturn S-II Seal Beach Facility (artist's concept).

Ground testing of launch vehicle stages calls for highly specialized facilities and extensive land areas. The Mississippi Test Facility (MTF), located in the southwestern corner of the State, is being developed for static test firings of high-thrust vehicle stages and engines. MTF offers the dual advantages of proximity to the Michoud Plant and location on a navigable waterway system. We have completed acquisition of a 13,424-acre tract of land that covers an area almost 5 miles square. Test stands and support facilities will be built on this site. The District Corps of Engineers Office at Mobile, Ala., NASA's agent for land acquisition, is obtaining an acoustical easement area of approximately 128,000 acres. In addition to the obvious safety factor, the buffer zone will protect the population against the high noise level that occurs during static test firings. Although residences will not be allowed in this area, economic activity, such as farming and lumbering, can continue.

Based on the current master plan (fig. 9–11), the Mississippi Test Facility will include test

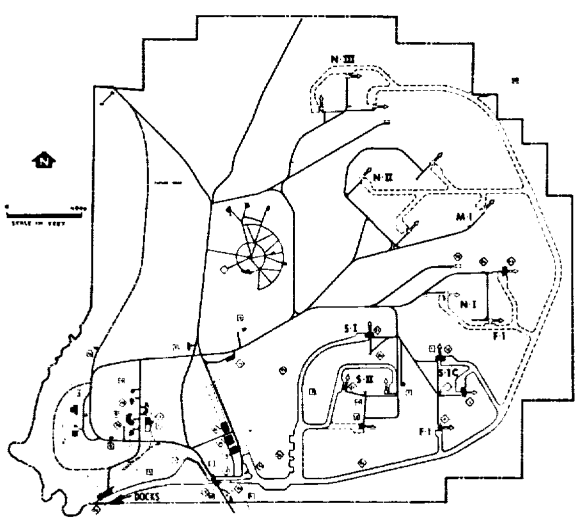


FIGURE 9–11.—Site plan for Mississippi Test Facility.

complexes for the first and second stages (S–IC and S–II) of the Saturn V vehicle. As the dashed lines on the master plan indicate, this plan provides for the necessary canal systems and site plans for eventual testing of the still larger stages and components of Nova-class vehicles. The initial phase of construction will require an estimated $200 million. The test complex for each stage will contain static test stands, a control center, and other related support facilities. An artist's conception of the S–IC test stand illustrates the type of test facilities that are being planned (fig. 9–12). The

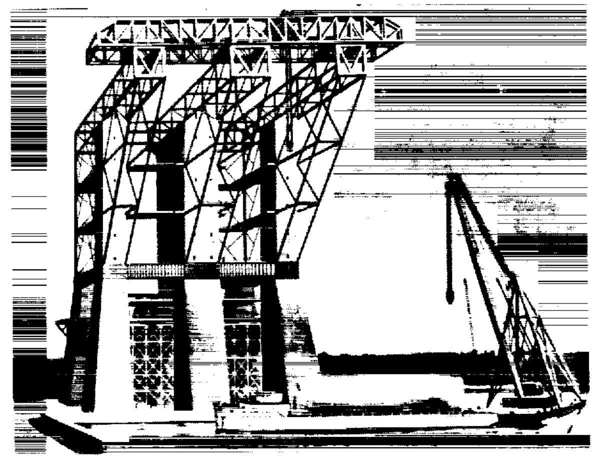


FIGURE 9–12.—S–IC stage dual static test stand (artist's concept).

first phase will also cover construction of approximately 20 support and service buildings. These buildings include an engineering laboratory, a site maintenance building, storage buildings for fuel and inflammable materials, an acoustical laboratory, and an electronics and instrumentation laboratory. In addition, a central control building, patterned after an airport control tower, will be constructed to house personnel and equipment for monitoring overall operations at the test site.

We are also constructing test facilities at west coast locations. For example, the development and acceptance test stands for the F–1 engine are being built at Edwards Air Force Base, Calif., and test stands for the J–2 engine are being constructed at Santa Susana, Calif.

Construction of launch facilities for manned space flight is one of our major efforts today. NASA/DOD agreements provided for mutual use of the original Atlantic Missile Range at Cape Canaveral. This original area, shown in the lower right-hand corner of figure 9–13, was principally developed by the Department of Defense. The requirements of Project Apollo have created an urgent need for additional land and facilities. In fiscal year 1962 NASA was authorized to acquire about 72,000 acres north and west of the existing area at Cape Canaveral. This land, called the NASA Merritt Island Launch Area, includes Areas I, II, and III on the map. Our target date for complete acquisi-

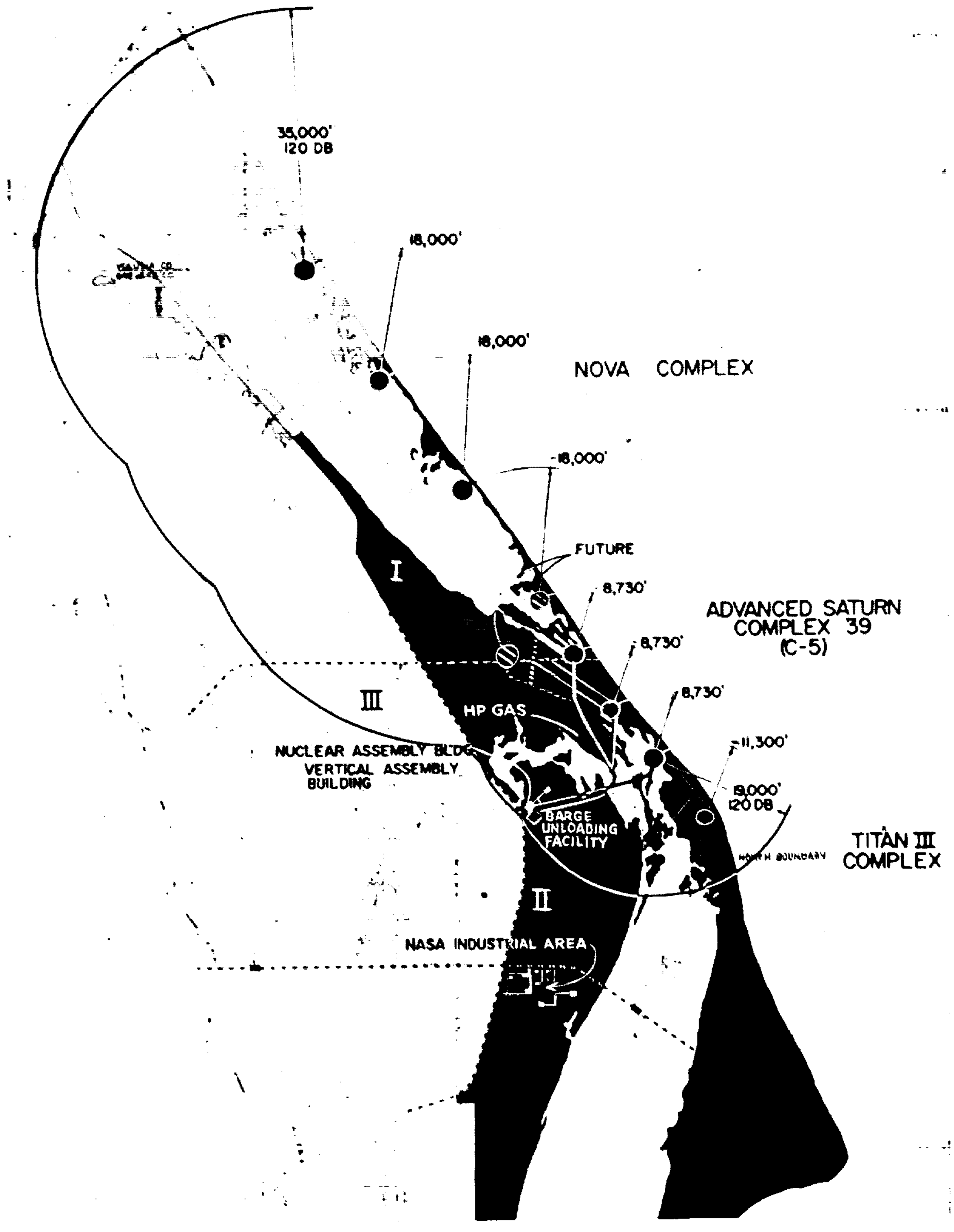


FIGURE 9–13.—NASA Merritt Island Launch Area.

tion of the tracts is September 1963. In fiscal year 1963 NASA received authorization to purchase about 14,800 additional acres in Volusia and Brevard Counties (upper left-hand corner of fig. 9–13). We plan to complete this land acquisition early in 1964. NASA, through the Launch Operations Center, will manage and serve as host agency at this new 87,000-acre Merritt Island Launch Area.

The majority of our current projects at the Launch Operations Center will be constructed in Areas I and II. These projects include Launch Complex 39, the Apollo mission support facilities, and other range-support facilities. About $293 million of a total $327 million that was approved in fiscal year 1963 for construction at the Launch Operations Center will be spent in developing the new area.

Figure 9–14 is an artist's conception of Launch Complex 39, which is probably the most

FIGURE 9–14.—Launch Complex 39, LOC.

complicated facility to be constructed at the Launch Operations Center. The estimated cost of this facility is about $450 million, which will be funded over several years. When completed, this vast complex will consist of a 48-story high Vertical Assembly Building (VAB) with four high-bay positions and a launch control center, at least three launch pads, and two crawler transporters. A system of heavy-duty roads will connect the VAB to each pad, several miles away. We also plan to have five launch umbilical towers, an arming tower, and numerous other support facilities and services. As indicated in paper 7, the launch concept represents a sharp departure from conventional methods of checking out, erecting, and launching vehicles. The flexibility of the Launch Complex 39 design will result in more efficient utilization of the facilities than has been possible in the past.

Checkout of the spacecraft will be performed in the Operations and Checkout Building, some distance from Launch Complex 39. Figure 9–15 is an artist's conception of the Operations

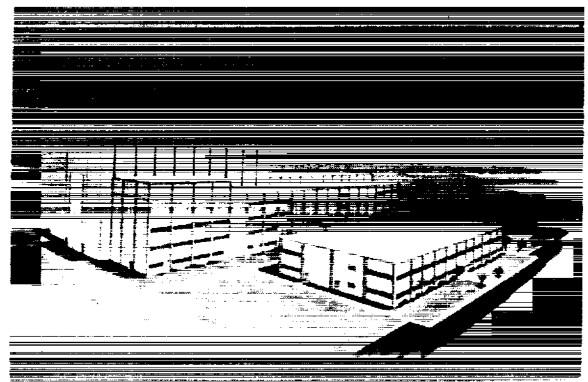


FIGURE 9–15.—Operations and Checkout Building, Launch Complex 39, LOC.

and Checkout Building, which is now under design and is scheduled to be operational by July 1964. Ground-breaking ceremonies for this building were held recently.

The closeup drawing in figure 9–16 reflects the current concept for the Vertical Assembly Building of Launch Complex 39. It will be one of the largest structures in the world, standing over 500 feet tall and covering more than 10 acres. Many significant engineering firsts will be established in this construction project. It will include, for example, the

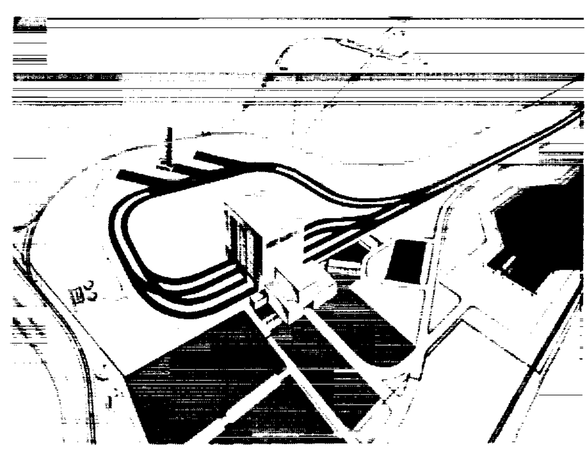


FIGURE 9–16.—Vertical Assembly Building, Launch Complex 39 (artist's concept).

world's largest doors, towering 456 feet from the ground to the top of each bay. The air conditioning required to maintain the proper environment within the building would be sufficient to ventilate the Empire State Building. Some 45,000 tons of steel will be used to construct the frame. Further, the structure will enclose the greatest volume of any known building in the world—130 million cubic feet—and will have an outside wall area of 1,250,000 square feet.

The first stage of the Saturn V vehicle will be placed on the transportable launcher in the high-bay area of the Vertical Assembly Building and will undergo a thorough checkout. After a check in the low-bay area, the upper stages will be assembled in a similar manner. When the upper stages and the Apollo spacecraft are mated with the booster, the final checkout will be performed and the crawler will carry the 360-foot-tall space vehicle to the pad. The giant crawler, moving along on tractor-like treads, will allow vertical transportation of the vehicle. The closeup drawing in figure 9–17 illustrates the proposed design of one of

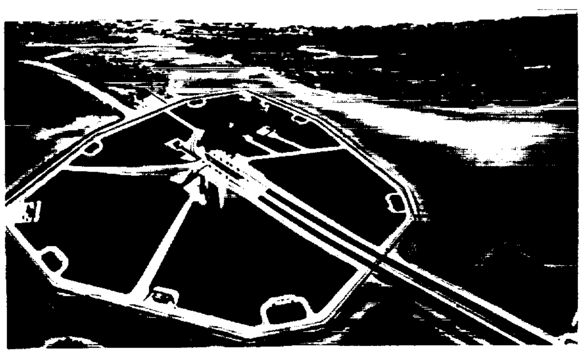


FIGURE 9–17.—Closeup drawing of one pad, Launch Complex 39.

the launch pads. The grade of the approach to the pad will not exceed 5 percent to assure safe, vertical transportation of the vehicle.

Cement and concrete requirements for launch pads vary, depending on the type of pad. For example, 3,600 cubic yards were required for Complex 34, where the Saturn I launches have taken place. The pads at Launch Complex 39 will call for approximately 5,000 cubic yards. These quantities represent only the pads themselves and do not include other items, such as the retaining walls and foundations.

This discussion has highlighted representative facilities projects in support of manned space flight. The projects offer many opportunities and unique challenges to large and small contractors. Our facilities effort ranges from support buildings and canal dredging to the construction of mammoth launch complexes, such as Complex 39. We rarely let a single contract for a major facility. As a general rule, facilities contracts are handled on a fixed-fee basis. The few exceptions to this rule occur only when extremely unusual requirements are involved. Construction is usually accomplished under several different contracts. For example, there may be one contract for site preparation, one for foundation, and one for superstructure, in addition to the contracts and procurements for equipment and instrumentation.

Industry is encouraged to explore the opportunities available at our construction locations. As a rule, the NASA Centers are responsible for awarding architect-engineering and construction contracts. In addition, NASA has taken full advantage of the tremendous experience and capabilities of the Army's Corps of Engineers and, to some extent, the Navy's Bureau of Yards and Docks. We have established cooperative agreements whereby we request these agencies to provide various types of services, such as facilities design, site selection, acquisition of real estate, construction contracting, and construction supervision and inspection. We have assigned most of the basic construction of facilities at the Manned Spacecraft Center, the Mississippi Test Facility, and the Launch Operations Center to the appropriate District Offices of the Corps of Engineers. These District Offices are located in Fort Worth, Tex.; Mobile, Ala.; and Jacksonville, Fla. We are also using the services of the Bureau of Yards and Docks for construction of the S–II facilities at Seal Beach, Calif.

Those interested in having a firm placed on the prospective bidders' lists should request information from the appropriate NASA Center or the Corps of Engineers District Office. When the names of OMSF contractors become known, requests may be made to be placed on their bidders' lists. We are relying on the ingenuity of U.S. industry to respond to the many challenges of the space age.

10 Space Sciences Program

EDGAR M. CORTRIGHT
Deputy Director, Office of Space Sciences

The NASA Space Sciences Program is a very broad one and encompasses many scientific disciplines and many types of flight hardware. The breadth of opportunity to explore space is limited only by nature. It includes the earth, moon, planets, sun, and stars. The breadth of the actual program to conduct such exploration is strictly man-limited. At this point in history we have undertaken a broad program to begin exploration of all the aforementioned areas. This effort involves the development of complex spacecraft and launch vehicle systems to perform automated missions in strange environments.

It is this hardware which is the prime subject of this paper. It is this hardware for which we rely primarily on industrial organizations. Without industry, we cannot do the job at all. Without extraordinary effort by industry, we cannot do the job well.

ORGANIZATION

The organization of the Space Sciences Program is shown in figure 10–1. The Office of Space Sciences reports directly to the Associate Administrator of NASA, who, in turn, reports to the Administrator and the Deputy Administrator. The Director of Space Sciences is supported by six directorates within the Office of Space Sciences and by an office at the Pacific Missile Range. The first four groups, Biosciences, Lunar and Planetary, Geophysics and Astronomy, and Launch Vehicles and Propulsion are concerned with the implementation and monitoring of our major space flight projects and the research which supports them. The Grants and Research Contracts Office provides contracting support for the Office of Space Sciences and other NASA elements dealing with universities and nonprofit organizations. In addition, this office provides the program direction for the sustaining university program. The Program Review and Resources Management Office provides staff assistance to the Director. In addition, the Office of Space Sciences is supported by the Space Sciences Steering Committee and its seven scientific subcommittees. The scientific subcommittees are composed of outstanding Government and university scientists who provide us with consultation and advice as to the proper scientific content of our various programs.

The Office of Space Sciences "contracts" directly with a number of NASA field centers and stations for the project management of our major flight projects and for the conduct of the supporting research which resides within this office. The day-to-day cognizance over this work is assumed by our various program directors. For example, the Ames Research Center in California has responsibility for the project management of the Pioneer and Biosatellite projects. The responsible directors within the Office of Space Sciences are the Directors of Lunar and Planetary Programs and of the Biosciences Programs, respectively. The work at the Jet Propulsion Laboratory on Projects Ranger, Surveyor, and Mariner is also under the cognizance of the OSS Director of Lunar and Planetary Programs. The Goddard Space Flight Center carries project management for explorers and monitors, the large earth-orbiting observatories, the Delta launch vehicle, and

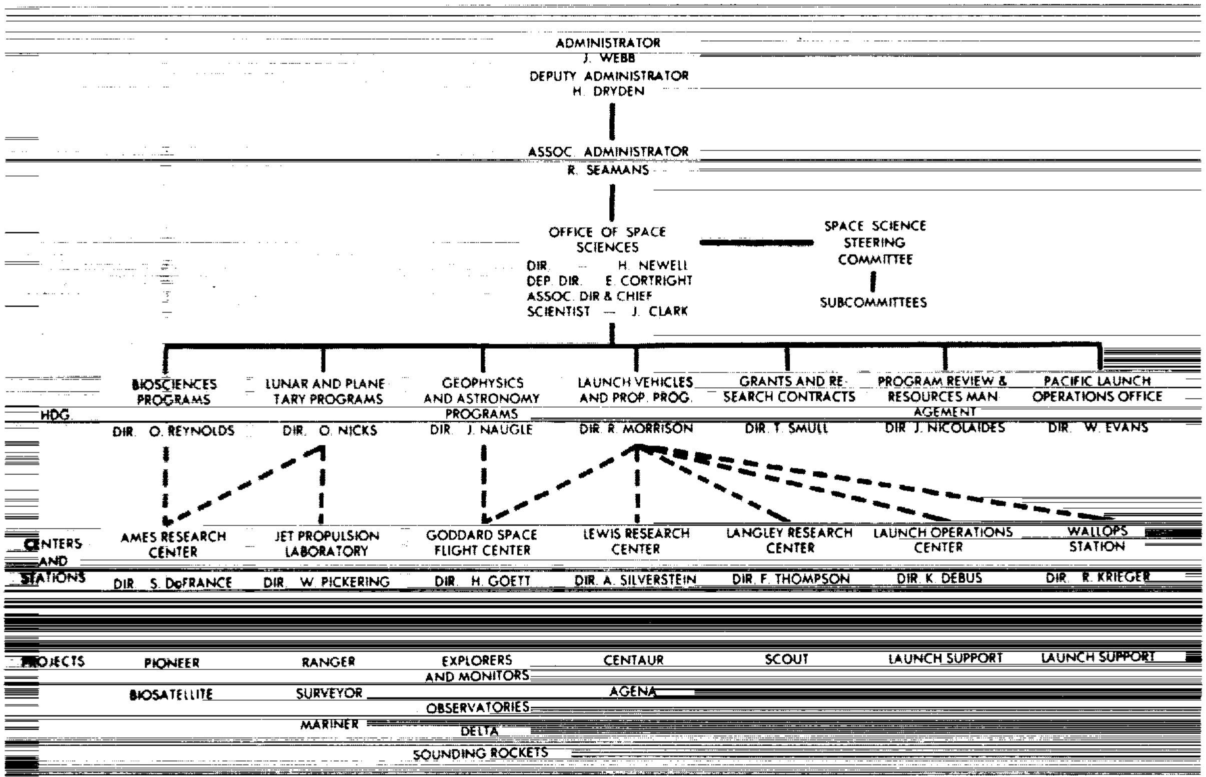


FIGURE 10-1.—Organization, Space Sciences Program.

sounding rockets. The OSS Director of Geophysics and Astronomy Programs monitors this effort. The Launch Vehicles and Propulsion Program is the responsibility of the Director of that office with project management for the various launch vehicles, namely, Delta, Centaur, Agena, and Scout, residing at the Goddard Space Flight Center, the Lewis Research Center, and the Langley Research Center. In addition, working arrangements exist with the Launch Operations Center at the Atlantic Missile Range and with the Wallops Station at Wallops Island, Va. The directors listed in figure 10-1 represent the key individuals responsible for implementation and execution of the NASA space sciences program.

FUNDING

NASA's space sciences program has grown steadily since NASA was established in 1958. (See fig. 10-2.) If the Congress continues its strong support for the OSS program and approves the budget substantially as submitted, the Geophysics and Astronomy program will increase from $174 million in fiscal year 1963 to $232 million in fiscal year 1964. The Lunar and Planetary program will increase from $226 million in 1963 to $331 million in 1964. The Biosciences program will increase from $25 million in 1963 to $41 million in 1964. The Launch Vehicle development program will increase from $121 million in 1963 to $149 million in 1964. Lastly, the Sustaining University pro-

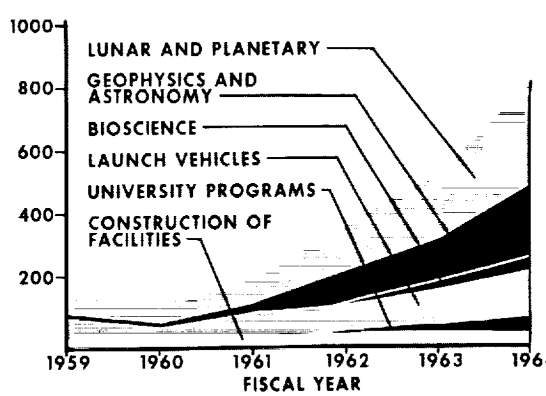


FIGURE 10-2.—Space Sciences Program funding (millions of dollars).

gram will increase from $31 million in 1963 to $56 million in 1964. The total program effort proposed for the Office of Space Sciences and its supporting field centers amounts to $810 million in 1964 compared with $579 million in 1963. Approximately 91 percent of these funds are spent in industry, nonprofit organizations, or universities.

MISSIONS ACCOMPLISHED

As a prelude, it might be of benefit to review the record of major space sciences missions accomplished since the beginning of the national space program. The scientific satellite flights from 1959 through 1962 are indicated in figure 10–3. Several important observations may be

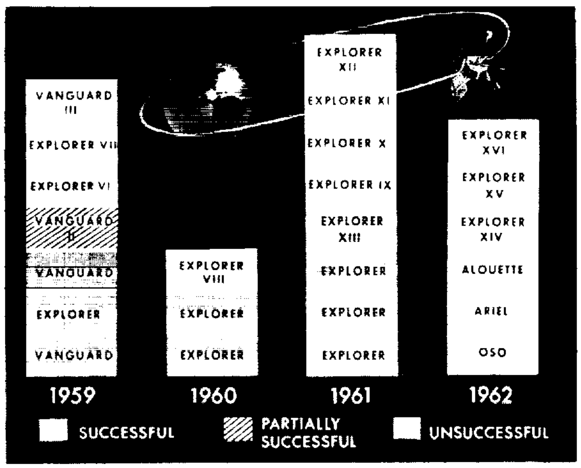


FIGURE 10–3.—Scientific satellites.

drawn from this figure. In 1962, we had 100-percent successes with our scientific satellites, whereas prior to 1962, the successes did not exceed 50 percent in any year. This dramatic improvement is due to two factors: first, we have learned how to design and develop reliable spin-stabilized satellites; second, we have capitalized on launch vehicles for satellite injection which are highly reliable such as the Thor-Delta. Another observation to be made is that the nature of the satellite missions has changed. In 1962, the first solar observatory was flown, which heralded in a new era of astronomical observation. In addition, 1962 saw the successful commencement of a cooperative flight program for space exploration with Canada and Great Britain. The Ariel satellite was instrumented by British scientists, and the Alouette satellite was developed entirely by the Canadians.

In the area of space probes, the present development stage is comparable to scientific satellites in previous years. As indicated in figure 10–4 five lunar and planetary missions were attempted in 1962. Of these five, only one mission can be counted a complete scientific success. This was the Mariner II which, on December 14, 1962, made history by flying on a predetermined trajectory close by the planet Venus. These space probes have called upon the most advanced technology in launch vehicles and unmanned spacecraft which this country has yet attempted. Early developmental problems have been encountered, both with the launch vehicles and the spacecraft, and strenuous efforts are underway to solve these problems.

GUIDANCE TO INDUSTRY

A prime purpose of the Second NASA-Industry Conference is to provide industry with some guidance to facilitate its own internal planning for future years. A review of the guidance provided at the First NASA-Industry Conference in 1960 and a comparison of it with the present status of our programs may be helpful. We can draw some useful conclusions from this.

The major projects within the Office of Space Sciences, the aspirations for these projects as stated at the 1960 NASA-Industry Conference, and the current status of the projects are listed in table 10–I. In 1960, a sounding rocket launch rate of 100 per year by 1962 was planned. Seventy-eight launches were actually made in 1962. In the category of small satellites, such as explorers, monitors, and international satellites, six per year were planned by 1963. In 1962, five were launched, and seven are planned for 1963. The Orbiting Solar Observatory was stated as entering its construction phase in 1960. It was successfully flown early in 1962. The Orbiting Geophysical and Orbiting Astronomical Observatories were just in the industry competition phase in 1960 and were planned to be launched at the rate of four per year by 1964. Actually, our first launch is planned for this year with three additional observatory satellites next year. The Pioneer program which existed in 1960 was to be concluded in that year. However, since then, we have begun a new series of Pioneers to run from 1964 to

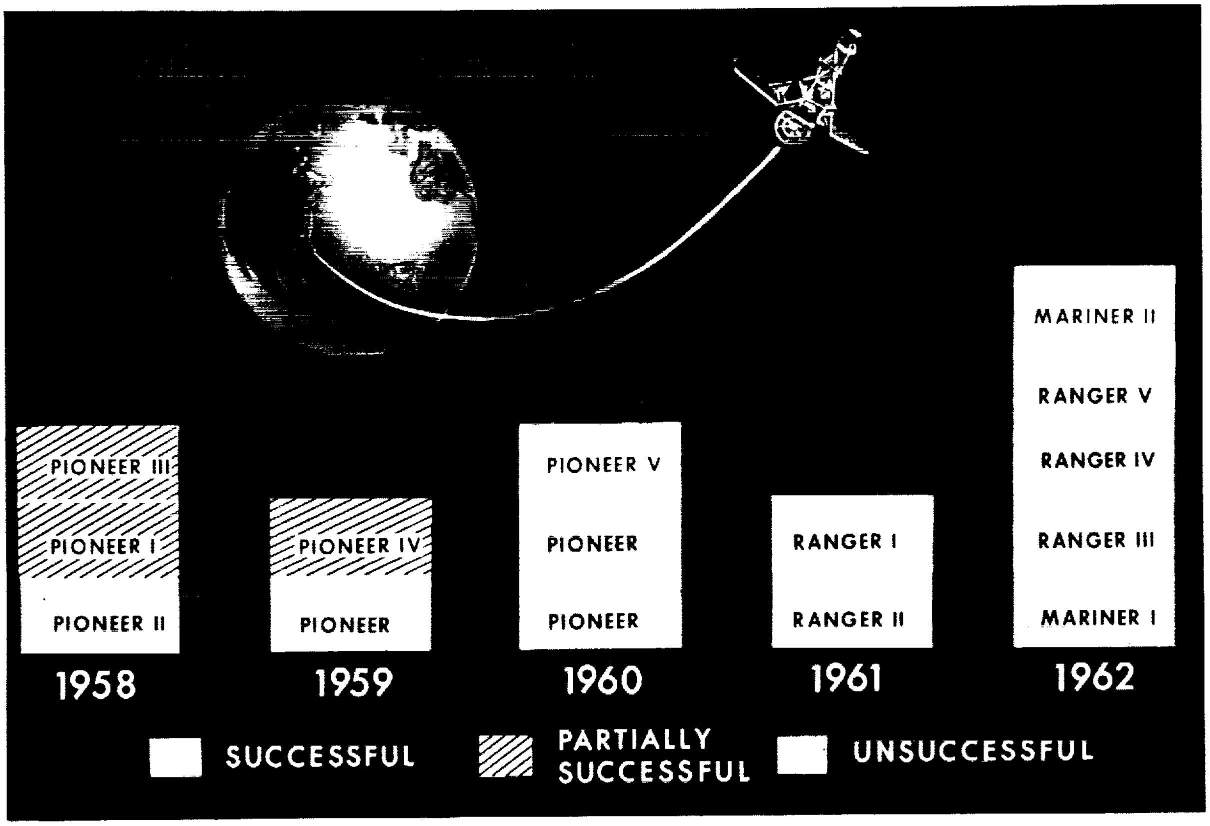


FIGURE 10-4.—Deep space probes.

1967. The initial series of Ranger flights was projected for completion in 1962. The first five flights were, in fact, completed in 1962, although with limited success, and the program has been expanded and extended. The Surveyor lander was in the design study phase in 1960 and was planned for first flight in 1963. Current plans are to fly the first Surveyors on test flights in 1964 with an operational version in 1965. The Surveyor orbiter was planned in 1960 for first flight in 1964. It now appears that our first orbiter flight will not be before 1965. The Prospector project was planned as a large lunar soft lander utilizing the Saturn launch vehicle. With the national decision to pursue a program to land man on the moon within this decade, the Prospector project was transferred to the Office of Manned Space Flight where studies are in progress of a reevaluated and reoriented project under the designation of Lunar Logistics Vehicle (LLV). In 1960, we planned a Venus flight in 1962 with a Mariner spacecraft derived from the Ranger design. This mission was successfully completed; however, it was necessary to switch from the Centaur to the Atlas-Agena rocket in midstream. The Voyager, an advanced planetary spacecraft, was planned for first flights in the 1965–66 time period. It now appears that this will not precede 1967. In 1960, there was no firm biosatellite program and only rather general plans to initiate one. This year, there are firm plans to go ahead with such a program.

Consider the light and medium launch vehicles which are used in NASA's flight programs. In 1960, NASA indicated that it would settle down to the use of Scout, Thor-Agena B, Atlas-Agena B, and Centaur. The Scout was planned to have the capability of 150 pounds at 300 miles and was to cost $1 million launched. The Scout is now considered fully operational with a current payload capability of 220 pounds. The cost of this vehicle is in fact $1 million. The Thor-Delta was envisioned as an interim vehicle costing $3½ million each. The outstanding success of this vehicle, with 14 out of 15 perfect flights, has resulted in its retention in the basic stable of launch vehicles at a

TABLE 10-I.—*Guidelines to Industry*

Programs	1960 Projections (NASA-Industry Conference)	1963 Reality
Sounding Rockets	100/yr by 1962	78 in 1962
Explorers, Monitors, and International	6/yr by 1963	Seven planned
Orbiting Solar Observatory	Under construction	Flown in 1962
Orbiting Geophysical Observatory	4/yr by 1964	Three planned
Orbiting Astronomical Observatory		
Pioneer	Conclude in 1960	New series for 1964–67
Ranger	Three launchings in 1962	Two launchings in 1962 and program extended
Surveyor (Lander)	First flight in 1963	First flight in 1964
Surveyor (Orbiter)	First flight in 1964	First flight in 1965
Prospector	Lunar "soft landing truck and several alternate payloads"	Manned space flight LLV
Mariner	Venus in 1962	Mission completed
Voyager	Planned for 1965–66	Planned for 1967
Biosatellite	No firm satellite program	Flights beginning 1964
Scout	150 lb at 300 miles, $1 million each	280 lb at 300 miles $1 million each
Delta	Interim vehicle, $3 million each	14 out of 15 successes $2.5 million each
Thor-Agena	Scientific and meteorological satellites from PMR	Alouette launched 1962; Nimbus scheduled 1963
Atlas-Agena	Lunar probes and scientific satellites from AMR	Ranger, Mariner, OGO, OAO, Gemini
Centaur	First launching: mid-1961	Launched May 1962; other delays

reduced priced of $2½ million launched. The payload capability of the Delta has also been increased by over 60 percent. The Thor-Agena is, in fact, being used as planned for scientific and meteorological satellites from the Pacific Missile Range. The Atlas-Agena is also being utilized as planned for scientific satellites and lunar probes, but is also being programed for planetary probes and for use as the target vehicle in the Gemini program. Centaur was planned for a 1961 launching, which was not achieved until May of 1962. Technical problems have resulted in other delays, and we will not have an operational Centaur until late 1964 or early 1965.

Although analysis of these comparisons illustrates the relative stability of the NASA program for the unmanned exploration of space, it also points up some of the real problems which confront us.

CHALLENGE TO INDUSTRY

In figure 10-5 those broad problem areas which will demand the best efforts of industry, as well as those of NASA, have been summarized. The first and foremost problem is that of reliability. In order to highlight this problem, reliability is plotted as a function of number of flights for several major military flight systems. It would have been preferable to draw data from advanced spacecraft, but insufficient flights are available to permit this. However, some of the complex military and civilian spacecraft which are being developed show indications of having the same initial bugs and low initial reliability as did these major military systems. This is perhaps not surprising, since our advanced spacecraft are generally as complex as these illustrative systems. However, the space program simply cannot tolerate such

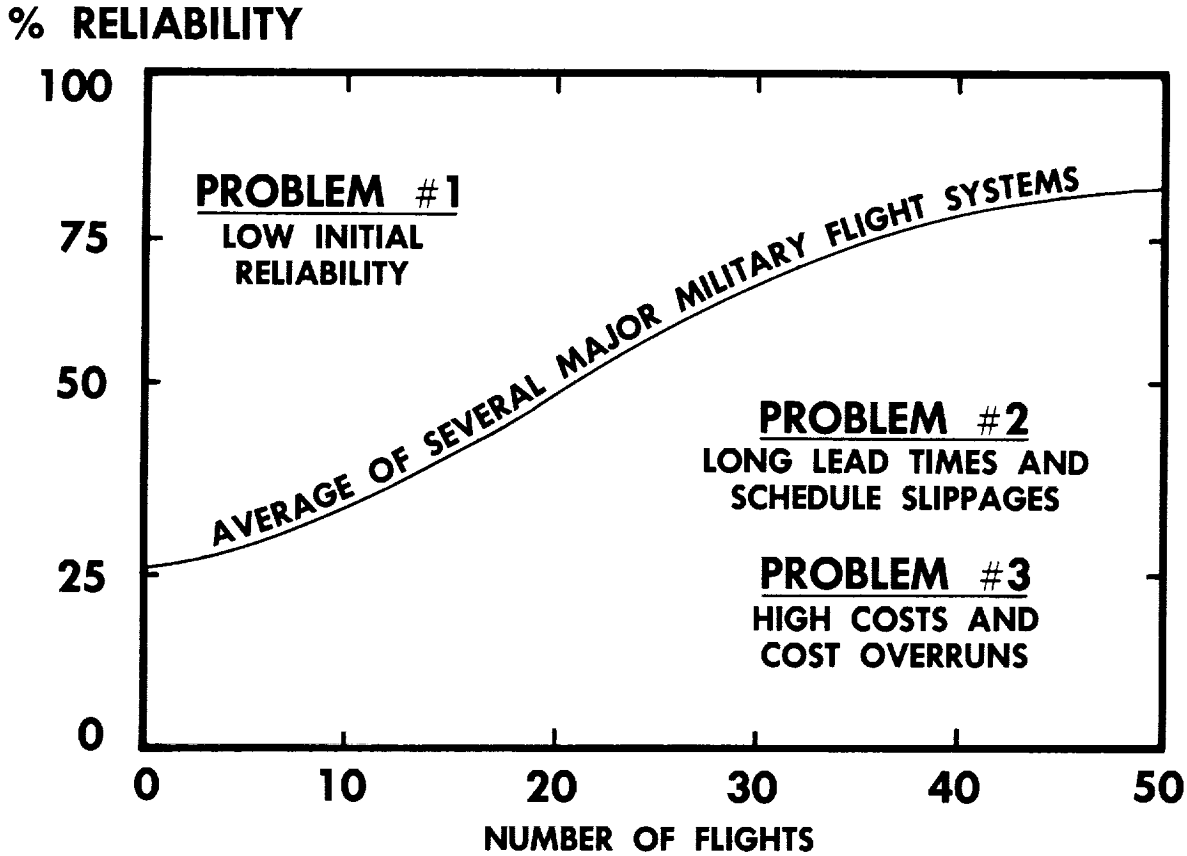


FIGURE 10-5.—The challenge to industry.

long development cycles. The systems shown here took approximately 20 flights on the average to achieve a 50-percent systems reliability. We must now develop techniques of realizing nearly 100 percent reliability from the outset in space projects. This point of view is widely shared within the Department of Defense, and a coordinated attack on this most difficult problem can be expected.

The second important problem is that of long lead times and schedule slippages. Long lead times are a function of the complexity of our systems and the procedures which are used by government and industry to implement our projects and develop the systems. Schedule slippages reflect this complexity as well as a propensity for injecting changes during the course of a project. Although these characteristics are typical of research and development programs, we should expend every effort and all of our ingenuity in improving performance in this area.

The last problem is that of high costs and costs overruns. This problem is directly related to the problems of achieving early reliability and holding schedules. A consideration of the present size of the space program should encourage the seeking of ways and means of reducing costs and getting more space program for the dollar.

This decade will undoubtedly see dramatic developments in the area of low volume production of high-quality electromechanical systems for use in space. These developments will set the pace for the rest of American industry and technology.

11 Geophysics and Astronomy

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There are many topics of mutual interest to NASA and industry. Industry is certainly interested in the direction and content of NASA programs. NASA is certainly interested in the participation of industry in these programs.

Industry is interested in the business which it may acquire from these programs. A company which has a piece of that business should understand the importance of the project so that it can transmit its interest and concern throughout the company and thereby help insure the success of the project. Industry is interested in the results from the program and their implications with regard to its products.

This paper will concentrate primarily on the objectives of the Geophysics and Astronomy program, the amount of money we have to spend, what we are spending it for, and what our future plans are. Some examples of the practical importance of the data we are taking will be included.

What is the Geophysics and Astronomy Program? What has it contributed to the Space Program? What has it contributed to technology?

OBJECTIVES AND ORGANIZATION

The Geophysics and Astronomy Program is concerned with the kind of scientific investigations which can be made with spacecraft which remain in the vicinity of the earth.

Figure 11–1 shows schematically some of the phenomena with which we are concerned. Satellites and sounding rockets are used to study the kind of light from stars which cannot penetrate the earth's atmosphere to telescopes on the ground. Similar techniques are used to study radiation from the sun and determine its effect on the earth's radiation belts, the aurora, and the atmosphere. We measure the magnetic fields in space and the flux of energetic particles.

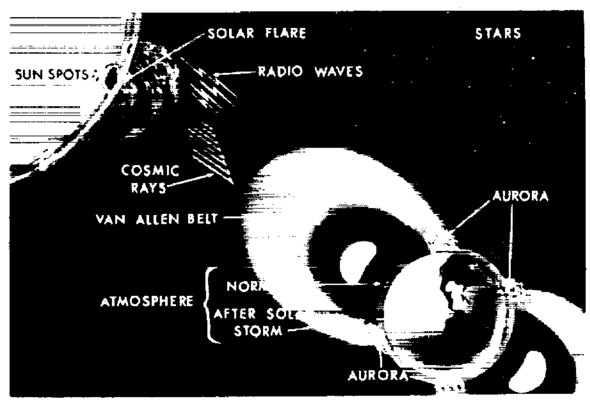


FIGURE 11-1.—Phenomena in the earth-space environment.

In order to establish and carry out a manageable program we divide these phenomena into four major scientific disciplines (fig. 11–2).

The study of stars by optical techniques is the responsibility of Astronomy. Anna, the Geodetic Satellite, is also a part of this program.

Solar Physics is a most important area of research. The sun controls the environment of earth and interplanetary space. Particles from solar flares are a major hazard to Apollo.

The discipline Chemistry really means the study of planetary atmospheres. This pro-

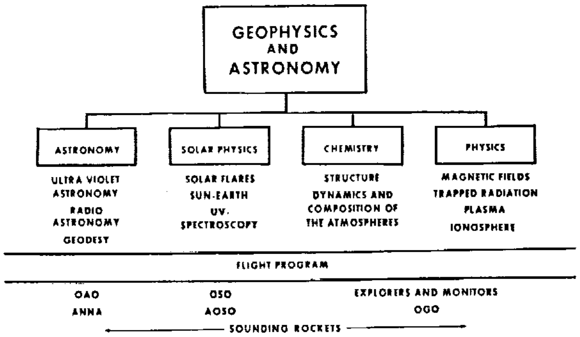


FIGURE 11-2.—Geophysics and Astronomy disciplines.

gram has produced a large amount of the data of practical importance on the dynamics and composition of the atmosphere.

The Physics program is concerned with radiation belts, magnetic fields, the ionosphere, solar wind, and interplanetary plasmas.

Associated with each of these disciplines are one or more major flight programs. The OAO and Anna support the Astronomy program. The OSO and the AOSO are the major vehicles used by the Solar Physics program. The Atmosphere Structure Satellite, S-6, was established for the Chemistry program. Explorers X, XII, XIV, and XV have already collected a large amount of data for the Physics program. The Orbiting Geophysical Observatory program, OGO, supports both the Chemistry and the Physics programs. The flight projects will be discussed in detail subsequently.

FUNDING

The amount of money spent in fiscal years 1962 and 1963 and the amounts asked of Congress in 1964 are shown in table 11-I. Note that the largest single item in the budget for fiscal year 1964 is the cost of launch vehicles.

TABLE 11-I.—*Geophysics and Astronomy Budget*

	Budget, Millions of Dollars		
	FY 1962	FY 1963	FY 1964
OSO	4.3	10.1	15.8
OAO	35.9	35.1	43.5
OGO	23.1	32.2	46.7
Explorers, Monitors, etc.	14.7	20.8	27.6
Sounding rockets	12.1	17.2	19.6
Supporting research	11.3	19.1	21.2
Launch vehicles	18.4	39.7	58.2
Total	119.8	174.2	232.6

The next two major items are the two observatory programs, OAO and OGO. These two items together take up 64 percent of our total budget. The total budget continues to increase, but at a slower rate than it has in the past years.

Table 11-II shows the same budget but broken down to indicate where the money is

TABLE 11-II.—*Geophysics and Astronomy—Distribution of Procurements*

	Distribution of Procurements, million of dollars		
	FY 1962	FY 1963	FY 1964
NASA salaries	10.1	14.6	19.0
Universities	11.9	24.7	30.5
Industry (spacecraft)	79.4	95.2	124.9
Industry (launch vehicles)	18.4	39.7	58.2
Total	119.8	174.2	232.6

spent. The largest single items are the $125 million for spacecraft and the $58 million for launch vehicles. This shows that about 85 percent of this portion of our funds immediately returns to industry. The actual figure would be slightly higher because a substantial portion of the money given to universities is spent with industry to buy their experimental hardware.

How do we decide what to spend the money for? How do we establish a new flight project?

The planning of a program and the establishment of its scientific objectives are the responsibility of NASA headquarters. The experimental requirements and the technical information required to plan the program come from a variety of sources, the scientific community, industry, and the NASA field centers.

After the need for and the objectives of a particular mission have been established, a center is given the responsibility for technical management of the project. For the Geophysics and Astronomy programs this is usually the Goddard Space Flight Center. The center draws up the specifications of the spacecraft required for the scientific experiment to be performed. If the spacecraft is very complex, the center will then ask industry to submit proposals for design studies. Several companies may be given contracts to conduct design studies. After completion of the design studies, one of these contractors will normally be selected to build the spacecraft.

In the meantime, letters will have been sent to the scientific community inviting them to submit proposals to conduct the experiments onboard the spacecraft. These proposals are reviewed by subcommitties of the NASA Space Sciences Steering Committee for their scientific merit and the capability of the proposer and his institution. The membership of these subcommittees consists of some of the most competent scientists from the scientific community and NASA centers. Final selection of the payload is made by the Space Sciences Steering Committee. After a scientist's experiment has been selected he is given a contract to design and manufacture the hardware for his experiment. This contract is given by the center with the responsibility for the project. The experimenter may elect to build the hardware at his own institution or subcontract to industry.

The scientists who do the experiments are primarily at universities, the NASA flight centers, and other Government laboratories. Approximately 60 percent of the experiments are performed by university scientists and the remainder by in-house scientists.

FLIGHT PROGRAM

Figure 11–3 shows the flight schedule. Plans call for: OSO, approximately two per year;

	CALENDAR YEAR					
	1962	1963	1964	1965	1966	1967
SOLAR OBSERVATORIES	1	1	2	2	3	4
ASTRONOMICAL OBSERVATORIES				2	1	2
GEOPHYSICAL OBSERVATORIES		1	3	3	2	3
EXPLORERS & MONITORS	3	5	5	5	5	5
INTERNATIONAL SATELLITES	2	2	5	2	2	2
SOUNDING ROCKETS	78	90	110	130	140	145

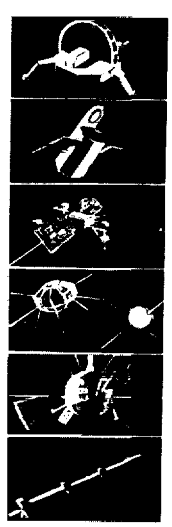


FIGURE 11–3.—Geophysics and Astronomy programs.

OAO, one per year; OGO, three per year; and the smaller Delta and Scout class satellites, about eight per year. The characteristics of these spacecraft and our future plans for them are discussed briefly as follows:

Orbiting Astronomical Observatory Program

Figure 11–4 shows a full-scale mockup of the OAO. The OAO is a precisely stabilized 3,300-pound satellite capable of accommodating a variety of astronomical experiments. It is to orbit the earth at an altitude of 500 statute miles at an inclination of 33°. The first launch is scheduled for early 1965 with an Atlas-Agena vehicle.

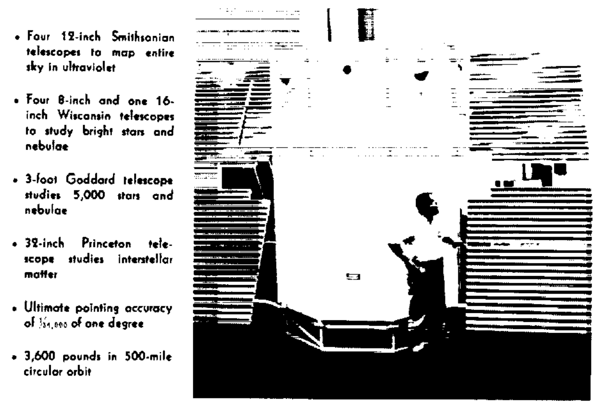


FIGURE 11–4.—Orbiting Astronomical Observatory.

Two main components make up the observatory—a standardized spacecraft which is being developed by Grumman—and the experiment packages. These scientific experiments, different for each OAO, will be supplied by leading astronomers.

Three spacecraft are now being built. The first spacecraft will carry two experiments, one supplied by Dr. Fred Whipple of the Smithsonian Astrophysical Observatory and the other by Dr. Arthur Code of the University of Wisconsin. The second OAO will contain an experiment supplied by Dr. James Milligan of the Goddard Space Flight Center, and the third, an experiment by Dr. Lyman Spitzer of Princeton University.

If we did nothing more than complete this program of three spacecraft, the total cost would be about $200 million, including launch vehicles, ground support equipment, and data processing and analysis. The fundamental reason for the high cost and the technical difficulties in this program is the requirement to select a particular location in the sky and point a 3,300-pound spacecraft at it, with an accuracy of about 0.1 arc-seconds for several hours.

The OAO is the most difficult and expensive project which we have underway. It will also undoubtedly be one of the most rewarding. The OAO does two things for astronomers. It enables them to study stars in the ultraviolet portion of the spectrum. This kind of light is absorbed in the upper atmosphere and therefore cannot be observed by conventional telescopes. The OAO will also increase the resolving power of the telescopes it carries by eliminating the effects of atmospheric turbulence on "seeing" conditions.

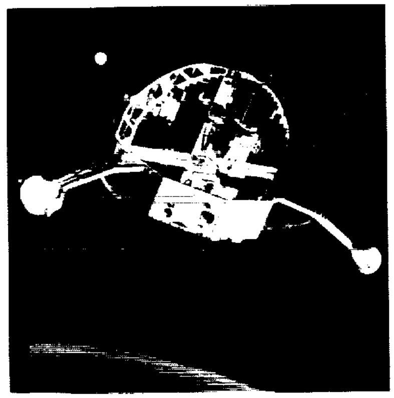
The study of stellar radiation in the ultraviolet region of the spectrum will provide a great deal of new and important information on the origin and evolution of stars and the processes which take place in their interiors. These results will increase our fundamental knowledge and undoubtedly change some of our concepts of nature. Ultimately, this knowledge will have an equally fundamental impact on technology, although when this will occur or what form it will take, nobody can say at this time. However, quite apart from the technological "spin-off" from the scientific results we are already getting some spin-off of a different sort in that some of the technology which has been developed for the OAO is being used in the Apollo Program.

Grumman has the prime contract for the OAO. General Electric, IBM, Westinghouse, and RCA have the major subcontracts for the OAO.

NASA has recently been given the responsibility for the Geodetic Satellite Program. We do not have an approved program as yet; however, we are planning one launch per year of a small 200-pound spacecraft, launched with a Delta or a Scout. We plan to use the spacecraft technology developed by the Department of Defense for Anna in this program.

Solar Observatory Program

Figure 11-5 shows OSO-I, the first observatory class spacecraft launched by NASA. OSO-I consists of two major parts, a sail containing solar cells and two experiments to be pointed at the sun, and a rotating wheel to provide stability. This wheel also carries experiments which do not require pointing at the sun, the batteries, tape recorders, and telemetry equipment.



PRIMARY MISSIONS:
- Spectrum and Intensity of Solar UV
- Solar Gamma Rays

LAUNCHED:
March 7, 1962

WEIGHT:
450 pounds

ORBIT:
Nearly a perfect circle

PERFORMANCE:
1200 hours of data to date

FIGURE 11-5.—Orbiting Solar Observatory I.

OSO-I was launched March 7, 1962, into a circular orbit, of low inclination, by a Delta vehicle. The spacecraft is still transmitting useful data.

Contracts are being negotiated for a total of eight of these spacecraft. We plan to launch about two OSO spacecraft per year for at least the next 5 years.

The total cost of an OSO, including the launch vehicle, the experiments, and the data processing is about $8.5 million.

Orbiting Geophysical Observatory

The Orbiting Geophysical Observatory (OGO) was conceived as a large, standardized spacecraft suitable for a wide variety of missions and capable of supporting as many as 20 to 50 experiments for scientific studies of the earth's atmosphere, magnetosphere, and interplanetary space near the earth. (See fig. 11-6.)

Continuous study of the phenomena associated with these regions throughout a complete

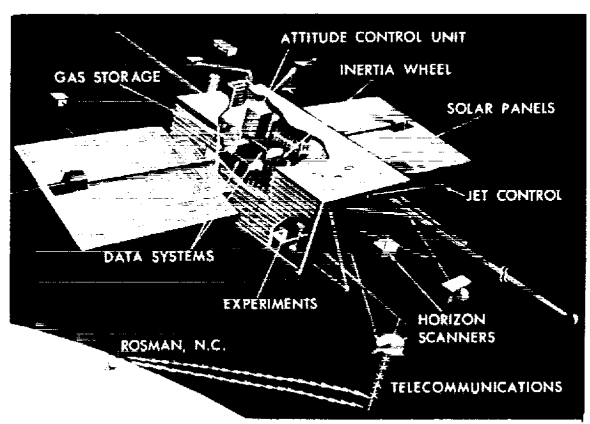


FIGURE 11-6.—Orbiting Geophysical Observatory.

solar cycle and during periods of solar flare activity is necessary to provide basic data for a better understanding of the earth-sun relationship leading to the observed phenomena and for the evaluation of the hazards of space to manned and unmanned space flight.

The OGO program will fulfill this requirement by the regularly scheduled launches and the development of a highly reliable spacecraft. The incorporation of the most advanced technology in the experimental studies and provision for the inclusion of specialized experimentation for further study of new discoveries will undoubtedly lead to significant advancement of our knowledge concerning our solar system, our galaxy, and the universe.

The spacecraft for these observatories has a simple rectangular-shaped box for the main body. A large number of experiments and the spacecraft subsystems are housed in the main body. The external booms are in a folded attitude during launch and are deployed after injection of the spacecraft into orbit.

Experiments which require preferred orientations or isolation from other experiments are mounted on external booms, in special Orbiting Plane Experimental Packages (OPEP), and in Solar Orientation Experimental Packages (SOEP) which are mounted outboard on the solar paddles. An important feature of the spacecraft is its stabilization or attitude control. The spacecraft orientation with respect to the earth is maintained so that one face of the main body is directed toward earth and the opposite face toward space. This attitude is necessary for the accurate pointing of earth- and space-oriented experiments. The solar array and the experiments in the SOEP's are continuously pointed at the sun. The OPEP has a separate control system, which alines it in the plane of the orbit.

At present, nine OGO missions have been scheduled. Three of these, the Eccentric Orbiting Geophysical Observatories, designated EGO-1 and EGO-2, and the Polar Orbiting Geophysical Observatory, designated POGO-1, are being fabricated by the Space Technology Laboratories (STL) under the technical direction of the Goddard Space Flight Center (GSFC). Each observatory will weigh approximately 1,000 pounds and will carry a scientific payload of 150 pounds. The EGO will be launched by an Atlas-Agena from the Atlantic Missile Range (AMR) and will be placed into a highly eccentric orbit, ranging from 150 nautical miles to 60,000 nautical miles, with an inclination of 31 degrees. POGO requires a near circular polar orbit with a perigee of 140 nautical miles and an apogee of 500 nautical miles; it will be launched by a Thor-Agena from the Pacific Missile Range (PMR).

Table 11-III shows a breakdown of the experiments which are on the first EGO and the first POGO.

The total planned funding for the entire OGO Program, covering nine missions and extending to the end of fiscal year 1966, is estimated at $249 million.

To implement the scientific requirement of obtaining data during a complete solar cycle, the OGO Program is planned for a period of at least 11 years.

TABLE 11-III.—*Orbiting Geophysical Observatories Experiment Summary*

Scientific discipline	Number		Weight, lb	
	EGO-1	POGO-1	EGO-1	POGO-1
Planetary atmospheres	3	7	14.3	74.8
Ionospheres and radio physics	6	4	39.0	17.0
Particles and fields	9	7	89.4	42.0
Astronomy	2	1	13.3	7.6
Solar physics	0	0	0	0
Total	20	19	[a] 156.0	[b] 141.4

[a] Includes an 8.1-lb backup experiment.
[b] 8.6 lb held in reserve.

Explorer and Monitor Program

The small explorer class satellites, weighing about 100 to 400 pounds and launched with the Delta and Scout vehicles, have contributed a tremendous amount of information about the environment in space. We will continue to use these in the program.

Figure 11–7 shows the satellites of this class which are scheduled for launch this year. One

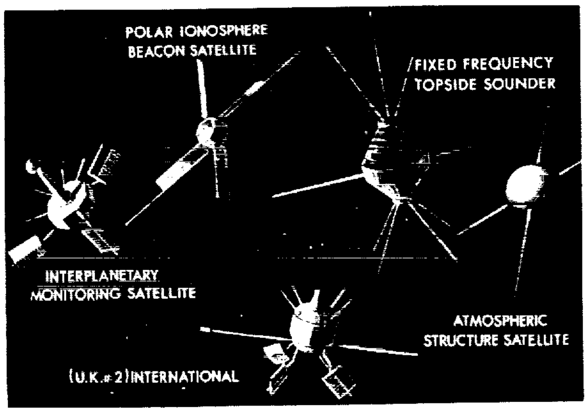


FIGURE 11–7.—Explorers and Monitors, planned 1963 launchings.

of these satellites, the Interplanetary Monitoring Platform, will be placed in a highly eccentric orbit to monitor the flux of energetic particles in space and the interplanetary magnetic fields. The data from this satellite will be very valuable in assessing the radiation levels in space. Three of these satellites are being built at present. We are conducting joint studies with AEC to use a nuclear power supply to replace the conventional solar cell power supply for the third spacecraft. Figure 11–8 shows the configuration which will be used.

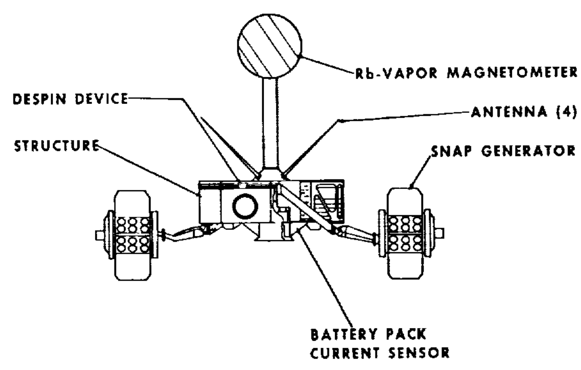


FIGURE 11–8.—Nuclear powered Imp.

Sounding Rockets

We launch about 70 to 80 rockets per year. We are using primarily the Nike-Cajun, Nike-Apache, Aerobee series, Argo D–4, and Argo D–8. These are used for vertical sounding covering the range from about 40 to 2,000 kilometers. The region from 40 to 200 kilometers is inaccessible to either balloons or satellites and hence can be studied only with sounding rockets.

We also use a number of sounding rockets to test new experiments prior to flight on a satellite. Figure 11–9 summarizes the type of vehicles used and the lead time required from conception to completion of an experiment.

FUTURE PLANS

What are our future plans for the solar observatories? Although the OSO will continue to provide a great deal of data about the sun it cannot carry the heavy experiments and point with sufficient accuracy to study the structure of a sunspot and determine the processes responsible for solar flares. Therefore, we are planning

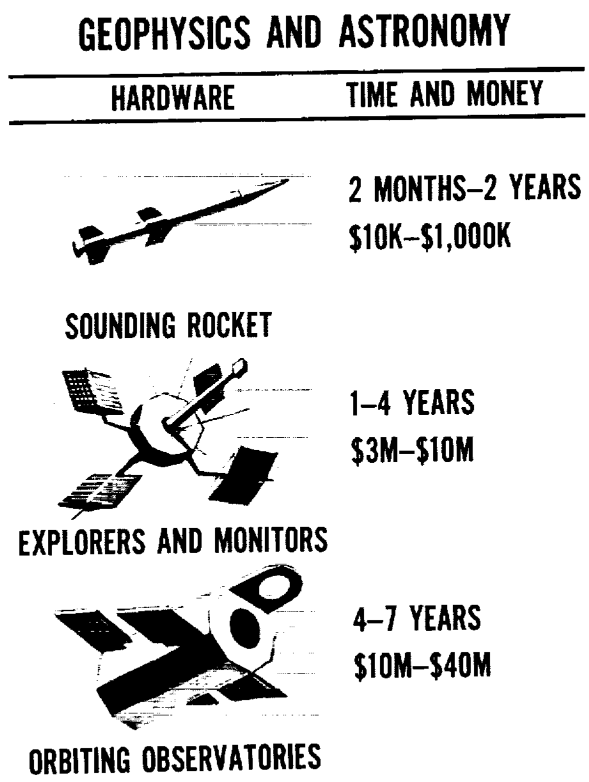
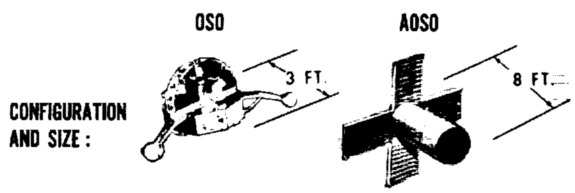


FIGURE 11–9.—Summary of Geophysics and Astronomy satellites.

an Advanced Solar Observatory, capable of pointing heavy experiments to a point on the sun with an accuracy of 5 arc-seconds.

Figure 11–10 shows the improvement of AOSO over OSO.



	OSO	AOSO
WEIGHT, POUNDS:	500	1000
POINT ACCURACY:	1/30 SUN DIAMETER	1/360 SUN DIAMETER
LAUNCH VEHICLE:	DELTA	AGENA

FIGURE 11–10.—Orbiting Solar Observatory, Advanced Model (AOSO); design studies being evaluated.

Three study contracts for AOSO have been given to:

Ball Brothers Research Corp.
Space Technology Laboratories
Republic Aviation Corp.

Upon completion of the evaluation of these proposals final plans will be made as to how to proceed with the flight hardware. The rapidity with which we proceed with the program depends on the action which Congress takes with regard to the program we have submitted. Present plans call for the first launch of AOSO in late 1966 or early 1967. The data from AOSO should be extremely useful in predicting the radiation levels expected for the Apollo flights, as well as for detailed studies of the solar flares expected at the next solar maximum beginning in 1967.

What are our plans for new kinds of spacecraft? We are interested in a radio astronomy satellite. At the present time radio astronomers are limited, by the ionosphere, to the use of frequencies above a few megacycles. There is a tremendous amount of information contained in the lower frequencies. This experiment requires the erection of a large antenna and a stabilization system. A gravity stabilization system might work for this. Such a system could give the coarse pointing accuracy of a few degrees required for the early survey measurements and could be launched by a Delta vehicle.

Also of interest are simultaneous measurements of the population of charged particles and the strength and direction of the magnetic field at widely separated points in the solar system. We will do this with a combination of satellites in the vicinity of the earth, probes going in close to the sun and others going far out from the sun.

It has been suggested that we should fly a very heavy satellite inside another satellite to study the gravitational field of the earth and the effects of relativity. The purpose of such a configuration is to eliminate as completely as possible the effects of atmospheric drag and solar radiation pressure.

We certainly anticipate a strong and vigorous program throughout the next decade. There will be a particularly vigorous program during 1967–1971. We will need to support the Apollo Program and we will also want to study the effects of the enhanced solar activity on interplanetary space and the magnetosphere. This enhancement will begin in 1967 and extend through 1971.

PROBLEM AREAS

Our major problem continues to be reliability. In particular, we need more reliable tape recorders or devices for storing information onboard the spacecraft. Tape recorders seem invariably to be the first component to fail on a spacecraft.

We also need to increase the lifetime of our satellites. Much of our work requires either monitoring the behavior of some phenomena in space or waiting for a particular event, such as a solar flare, to happen. Consequently, as we increase the useful life of our spacecraft we also cut the costs of the program and help insure that we get the data we need.

There is another mutual problem which we have. We have not planned for developmental shots of our spacecraft. All our spacecraft carry full complements of experiments and are designed to work the first time they fly. This means that industry must develop the necessary project teams and managerial skills to design, build, and test a spacecraft to insure that it will work the first time. This requires, first of all, competent people; second, it requires an adequate initial design of the spacecraft; and third, it requires a very thorough testing program of all components at all stages in the development of the spacecraft culminating in a final testing program of the entire spacecraft to insure that it will work in space. In short, where there has been a successful program, there has also been a group of wise and dedicated people who knew what the objective of the program was, who used considerable ingenuity in design, who selected components with care, and who, above all, were able to figure out the proper hurdles for their brain child before putting it in space.

PRACTICAL RESULTS

A review of the practical importance of a few of the results of the program may be of interest. The results from the first U.S. satellite, Vanguard I, showed that the mass of the earth was not distributed uniformly. Figure 11–11 shows the significance of this to a Gemini

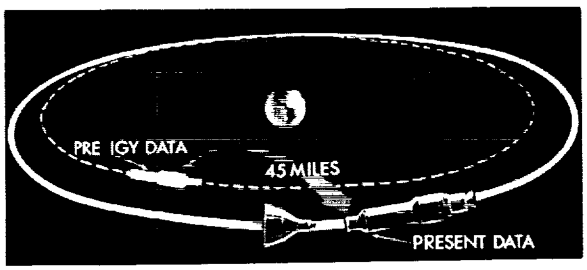


FIGURE 11–11.—Gravitational effects on orbital computation.

rendezvous. The dashed line shows where we would predict a Gemini capsule to be after a week in orbit based on pre-IGY data. The solid line shows where it actually would be based on the data obtained so far in the space program. We need even better data than these to predict the behavior of a communications satellite in a 24-hour orbit. These data will be sought in the follow-on Geodetic Satellite Program.

Figure 11–12 shows the radiation problem for Apollo. There was much controversy regarding the radiation problem for Apollo a year or so ago, when there was a question as to whether man could fly in space because of the radiation hazard from the sporadic solar beams. Figure 11–12 shows the state of our knowledge at that time. At that time almost all our data had been obtained by experiments carried on balloon flights which could only get into the air several hours after a flare began and which could only detect particles which could get through the atmosphere above the balloon. The air above the balloon was the equivalent of about 2 inches of aluminum. Therefore, we could predict what would happen to an astronaut launched 2 hours after a flare began and in a capsule of aluminum 2 inches thick. We could only make

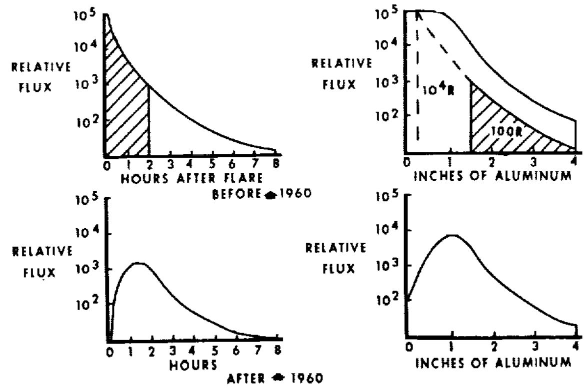


FIGURE 11–12.—Solar proton radiation.

some very rough guesses as to what might happen to an astronaut in a more realistic capsule of ⅛-inch-thick aluminum, who was on his way to the moon when a flare occurred. If one assumed that the radiation measured by the balloon gave a true picture, that is there were no particles coming until 2 hours after the flare and that none had been removed by the atmosphere above the balloon, the total dose the astronaut would receive would be proportional to the area under the upper left curve and the radiation would have been no problem. On the other hand, if one assumed that, as shielding was made thinner, the number of particles able to enter the capsule increased, and as measurements were made closer to the beginning of a flare the number of particles also increased, then the total dose would have been proportional to the area under the upper right curve, and the shielding required would have ruled out Apollo in its present configuration. This was the situation at the beginning of 1960. In November 1960 the sun presented us with a major flare accompanied by large numbers of energetic particles. By this time Explorer VII was in the air, we were flying balloons continuously, and we had rockets on standby to study such an event. Out of all these measurements on that flare and the subsequent measurements with Explorer XII we have learned that neither of these extreme assumptions was quite correct, but that the number of particles rises slowly after a flare to a maximum an hour after the flare begins. An unprotected astronaut in space, it is true, would get a lethal dose of radiation but it is possible to carry sufficient shielding on Apollo to reduce the dosage to a permissible level.

There is a very important point here. The most significant contribution which science made in this operation was not the measurements but the discovery that there *was* a radiation hazard. Just 2 years earlier, at the beginning of 1958, the existence of this hazard was unknown. The discovery that it existed was made by people studying cosmic rays, a study which seemed to be as "pure" and unapplied science as there was. Not even the most imaginative could conceive of any practical importance of cosmic rays. We were learning about nature but we were not "advancing technology."

The lesson to be learned from this experience is that we must have as a fundamental long-term national goal the maintenance of a strong vigorous basic research program. Without this goal we will not be able to meet such short-term goals as putting a man on the moon in this decade.

12 Lunar and Planetary Programs

ORAN W. NICKS

Director, Lunar and Planetary Programs, Office of Space Sciences

The basic objectives of the Lunar and Planetary Programs can be stated as follows: The exploration of the Sun, the Moon, the planets and their satellites, comets, astroids, and interplanetary space; and the development of technologies vital to advancing capabilities for all space flight. The knowledge obtained in the future using unmanned spacecraft will initiate rapid increases in our scientific understanding of the solar system, and at the same time will provide essential information for development of manned space flight.

The overall flight schedule for the Lunar and Planetary Programs is shown in figure 12-1. Those portions of the flight programs that have been approved are shown by the filled bars, while elements of the flight program that are under study are shown by the dashed lines. The flight projects included under the Directorate of Lunar and Planetary Programs are separable into three groupings:

(1) Lunar exploration
(2) Planetary exploration
(3) Exploration of interplanetary space and the Sun

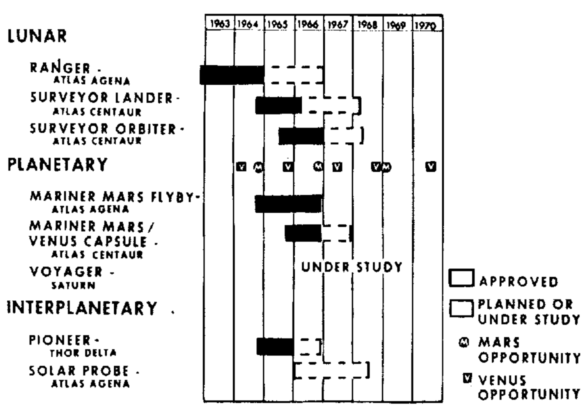


FIGURE 12-1.—Flight schedule for Lunar and Planetary Programs.

There are three programs currently underway to explore the Moon. The Ranger Program, which was initiated with the launch of Ranger I by an Atlas-Agena in 1961, will probably be continued through 1965. Ranger spacecraft are designed with a capability to hard land scientific payloads, to take closeup pictures of the lunar surface, and to make measurements in the vicinity of the Moon. Following the Ranger is the Surveyor Lander Program, based on use of the Atlas-Centaur. These spacecraft are designed for soft lunar landings and are to perform a variety of scientific experiments while operating on the lunar surface. The first Surveyor flight is scheduled for 1964. The program is currently approved into 1966 and will no doubt be extended. The Surveyor Orbiter Program will overlap with the Lander Program, starting about 1 year after the first Lander. In addition to obtaining large area photographic coverage of the Moon, the Orbiter will team up with the Lander for investigation of specific Surveyor Lander and Apollo landing sites. The Orbiter, also to be launched by the Atlas-Centaur, is scheduled through 1966. Before the end of this decade, man will personally begin to explore the Moon. It is anticipated, however, that unmanned missions will be continued to explore those regions of scientific interest not readily accessible to man.

Our first planetary mission was the Venus fly-by of Mariner II on December 14, 1962. Mariner II performed exceedingly well and large quantities of very useful scientific data were obtained. Similar spacecraft, also to be launched by the Atlas-Agena, are being prepared for fly-by of the planet Mars. First flights to Mars are scheduled for the 1964 opportunity. Flights in 1966 are also scheduled for this type Mariner.

The next step in planetary exploration is planned to begin in 1965, using larger Mariner spacecraft to be launched by the Atlas-Centaur. The current plan calls for a Venus mission in 1965 and a Mars mission in 1966. It is planned that these Centaur-class Mariners will be used on subsequent planetary missions extending at least through 1967. Voyager is being studied for possible orbiter and lander missions to Mars and Venus using the Saturn-class of launch vehicles. It is not, however, an approved flight development project at this time.

The phenomena occurring within interplanetary space are of great interest to scientists, and to engineers designing unmanned and manned spacecraft. Most of our planetary spacecraft, such as Mariner II, will be instrumented to measure scientific phenomena in interplanetary space on their long journeys to the planets. However, because of the spacing of the planetary opportunities and the particular trajectories that these spacecraft travel, it is necessary to augment their interplanetary results with data from specially designed interplanetary monitoring spacecraft. The relatively simple Pioneer spacecraft, to be launched by Thor-Delta vehicles, is scheduled for flight beginning in 1964, during the International Quiet Sun Year. Competitive selection of a contractor for designing, developing, and producing this spacecraft is to begin soon. Finally, we are studying a solar probe which might travel to within ⅓ astronomical unit (about 30 million miles) of the Sun. This spacecraft is to be launched by the Atlas-Agena. Other missions, such as exploration of other planets, are also under study.

Each spacecraft will now be described briefly and its status indicated. Shown in figure 12–2 is a Ranger configuration. The Ranger project is being managed for NASA by the Jet Propulsion Laboratory in Pasadena, Calif. This

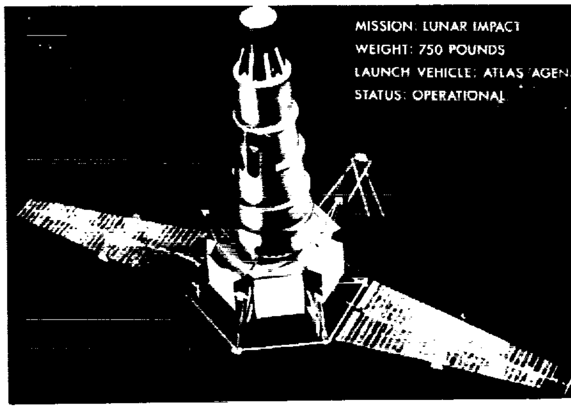


FIGURE 12–2.—Ranger spacecraft.

spacecraft weighs around 750 pounds, is attitude-stabilized, and is designed for the Atlas-Agena. It is operational, having been initially launched in 1961. Three more spacecraft were launched last year. Because this spacecraft has been troubled with initial "bugs," it is currently undergoing a detailed design review and extensive test program. We expect to initiate the next series of Ranger launches late in 1963.

Figure 12–3 is a photograph of a Surveyor Lander mockup. The Surveyor is to be

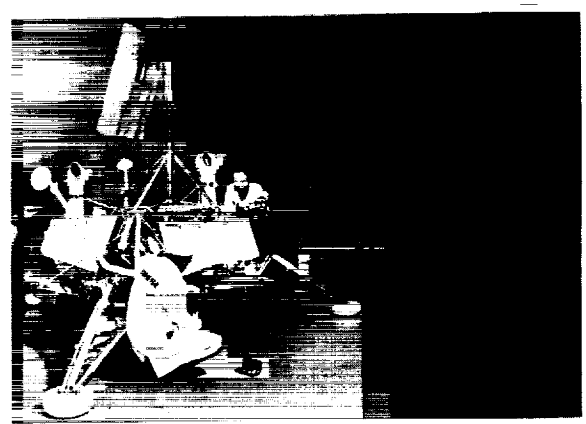


FIGURE 12–3.—Mockupof Surveyor lander.

launched by the Atlas-Centaur vehicle, and its weight will be about 2,100 pounds. The Surveyor Lander is currently being developed by the Hughes Aircraft Co., under the direction of the Jet Propulsion Laboratory where NASA has assigned project management responsibilities. The project is well along in its development phases, and as mentioned previously, is expected to undergo first flight tests in 1964. Some study effort is being considered to explore

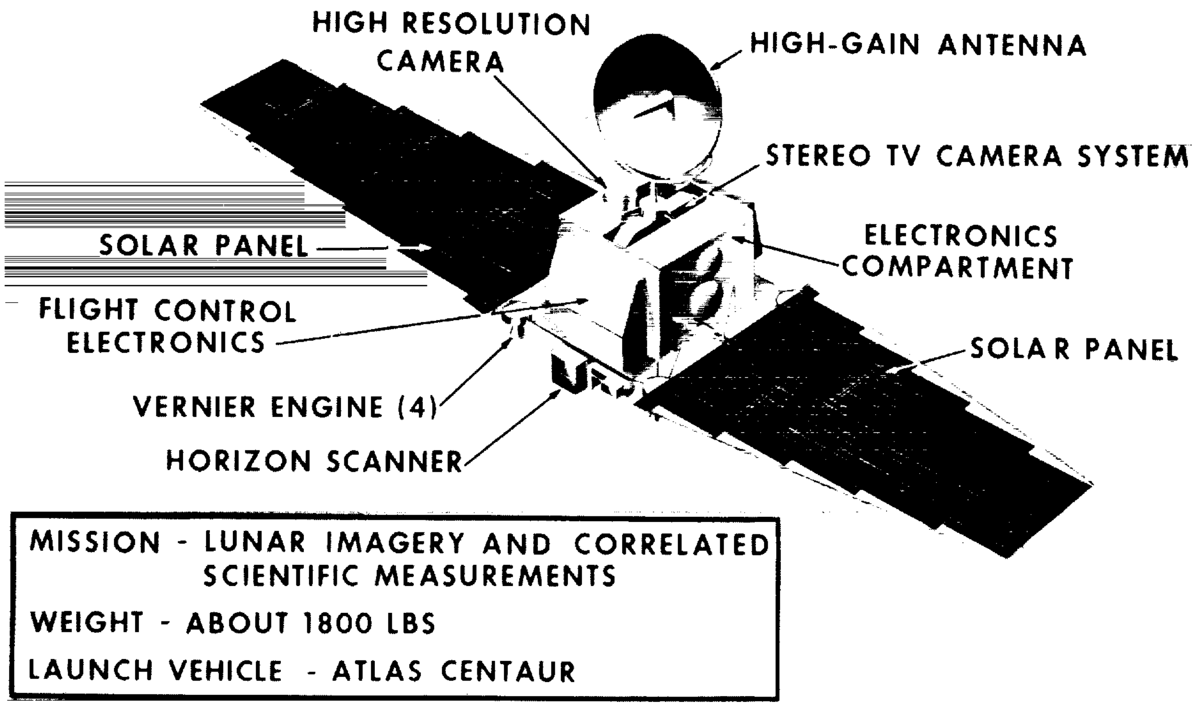


FIGURE 12-4.—Surveyor Orbiter.

special applications of Surveyor Lander spacecraft for follow-on missions.

Figure 12-4 is an artist's conception of the current design for the Surveyor Orbiter. As now planned, the Orbiter will be an outgrowth of the Surveyor Lander and will be launched by the same launch vehicle, the Atlas-Centaur. The design for the Orbiter is currently under detailed review.

A design concept of the Mariner spacecraft for fly-by of Mars is shown in figure 12-5. Although different in appearance, this spacecraft is technically very similar to Mariner II, which flew by Venus in 1962, and uses many of the same components. It is in the 500-pound class, designed to be launched by the Atlas-Agena. This spacecraft is being prepared by the Jet Propulsion Laboratory with the participation of a large segment of industry on a subcontract basis.

Figure 12-6 is a photograph of a mockup of a Mariner spacecraft for Mars/Venus capsule

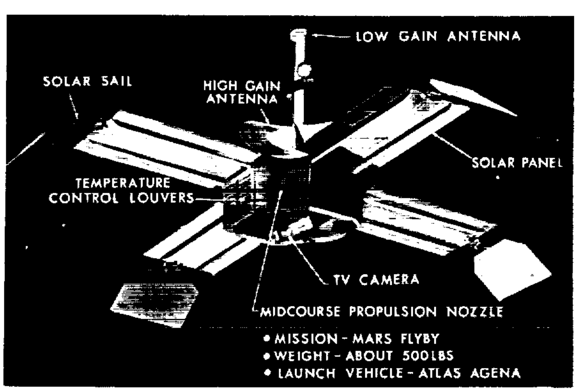


FIGURE 12-5.—Mariner spacecraft design for fly-by of Mars.

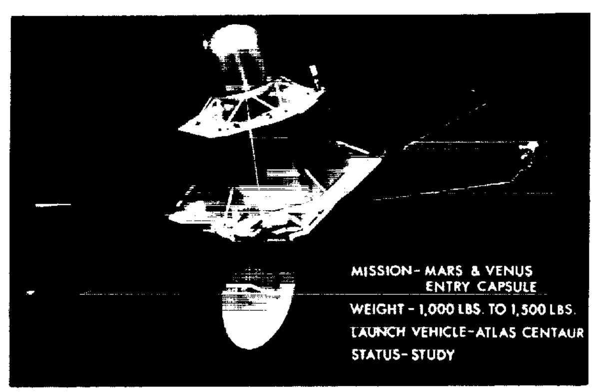


FIGURE 12-6.—Mockup of a Mariner spacecraft for Mars/Venus capsule.

entry and landing. This photograph is only one particular design concept of several which are being studied. The Mariner spacecraft for this mission is to be launched by the Atlas-Centaur and is in the 1,000- to 1,500-pound class. The final configuration and plans for implementing this project are presently under study, with decisions expected early in 1963.

The Pioneer, shown in figure 12–7, is a light-weight spin-stabilized spacecraft. It will

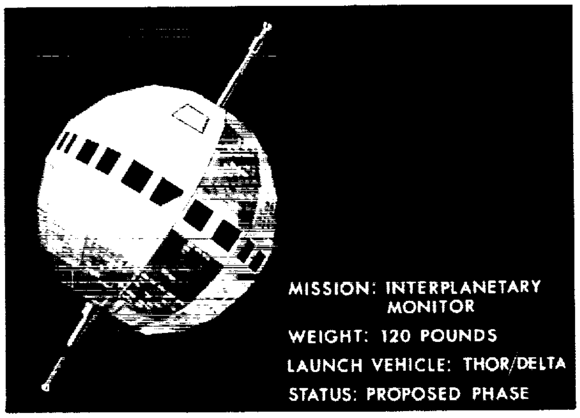


FIGURE 12–7.—Pioneer (artist's concept).

weigh about 120 pounds, and will be launched by the Thor-Delta. A request for proposals on this spacecraft was sent out in late January 1963 by the Ames Research Center for spacecraft design, development, and fabrication.

Table 12–I summarizes the missions which are currently under study. The Voyager mission is conceived to orbit either Mars or Venus, and to land capsules on either planet. If the Saturn IB vehicle is used, Voyager spacecraft may weigh on the order of 7,000 pounds. Industry studies of possible Voyager designs are planned to begin before the summer of 1963, with study proposals to be solicited by Headquarters.

To augment the results of the Pioneer and to probe close to the Sun, a Solar Probe spacecraft is being considered which might weigh on the order of 300 pounds and be launched by the Atlas-Agena. Industry studies are expected to be solicited by the Ames Research Center in the spring. In addition, we are studying missions to the other planets, flights out of the plane of the ecliptic, and missions to explore comets and asteroids.

We anticipate the development of spacecraft capable of trips to Jupiter, Saturn, and Pluto

TABLE 12–I.—*Missions Under Study*

VOYAGER	
Mission:	Mars and Venus orbit and land
Weight:	3,000 to 8,000 lb
Launch vehicle:	Saturn
SOLAR PROBE	
Mission:	Probe of Sun to about 1/8 astronomical unit
Weight:	About 300 lb
Launch vehicle:	Atlas-Agena
OTHER	
Outer planets	
Out of the plane of the ecliptic	
Comets	
Asteroids	
Escape from solar system	

in the 1970's. Since it takes about twice the energy for a trip to Jupiter as it does to Mars, nuclear and/or electric propulsion will probably be utilized for these types of missions. Nuclear powerplants will probably be required for such missions because of the extreme requirements for communication power. The research being conducted at various NASA centers and being sponsored by the offices of Advanced Research and Technology will pave the way for such missions.

Table 12–II summarizes the programs and the responsible individuals for these programs. The Program Chief at NASA Headquarters, the cognizant NASA center, the Project Managers, and the industry contact are shown.

There are some unique problems to be faced in the planetary programs, which industry may be called upon to solve. The *usual* problems that exist for any spacecraft (such as light weight, reliability, low power requirements, etc.) are always present.

The first of our unique problems is long lifetime operation. In the Mariner II fly-by of Venus the spacecraft had to function for 109 days. The trip to Mars will require roughly 6 months. When spacecraft travel to the outer planets, the trips will be measured in years, perhaps on the order of 3 to 5 years. All the equipment on board, all the scientific instruments, all the communications gear, the electrical systems, and so forth must operate properly from months to years. Long life components, special redundant systems, and test techniques to prove these capabilities are essential.

In the exploration of the planets, one prime objective is the search for extraterrestrial life.

TABLE 12-II.—*Program Responsibilities*

Project	NASA Headquarters Program Chief	Center Project Manager	Center Industry Contact
Ranger	N. W. Cunningham	JPL—H. M. Schurmeier	JPL—G. Lawrence
Surveyor	B. Milwitzky	JPL—W. E. Giberson	JPL—G. Lawrence
Mariner	F. Kochendorfer	JPL—J. N. James	JPL—G. Lawrence
Pioneer	F. Kochendorfer	Ames—C. Hall	Ames—C. Hall
Advanced Projects:	D. P. Hearth		
Voyager		Unassigned	
Solar probe		Ames—H. Matthews	Ames—H. Matthews
Other missions			

Consequently, we must sterilize the spacecraft so that we do not contaminate the planet, and thereby negate any results that might be obtained from scientific experiments. Present sterilization techniques reduce reliability, are expensive, and time consuming. The only sure technique used to date, long hours at high temperatures (above 125° for 24 hours), is unacceptable in many instances because of artificial aging effects. New components and techniques are essential.

A third problem area is that of communications. An unmanned spacecraft must be able to execute commands as directed from Earth many millions of miles away. The data its instruments obtain must be sent back to Earth, or the mission is useless. As our experiments become more involved, we must have the ability to transmit large quantities of data over extreme distances back to Earth. This requirement calls for high-gain systems of transmission, and may involve directional antennas, storage devices, and special techniques for rapid data handling.

Finally, there is the problem of operation within the planetary atmospheres. Sufficient data do not exist at the present time to cope satisfactorily with design problems associated with sending spacecraft to other planets. It is imperative that studies be conducted to ascertain the nature of probable planetary atmospheres, and that developments of entry techniques be pursued if we are to prepare successfully for planetary missions. Venus is a good example for illustrating the nature of the problem. Entry velocities will be higher than any previously experienced on Earth, due to the nature of transit trajectories and the orbital characteristics of the planet. In addition to the high velocity, uncertainties in the nature and composition of the Venus atmosphere make the spread of possible conditions extremely compromising to capsule design.

This brief résumé of NASA Lunar and Planetary Programs has covered, to the extent possible, our best knowledge of our plans. These are dynamic programs, however, and plans are subject to change. Industry studies and developments figure importantly in our planning effort; we expect to maintain the close coordination with industry which will allow the continuous interchange essential to both industry and NASA.

13 Biological Problems Related to Space

ORR E. REYNOLDS

Director, Bioscience Programs, Office of Space Sciences

The biological sciences have been very slow in getting started in the space sciences. This has been for several rather understandable reasons. First of all, biologists have had a very difficult time visualizing important problems in their field of science related to the space sciences which are capable of solution in the present state of our technology. Second, after these problems have been envisioned, it has turned out that the technology itself was at the far limit of the state of the art. We are wrestling right now with our ability to generate the technology which will allow the solution of a number of important biological problems related to space. In this respect we will be relying very heavily on American industry and we earnestly solicit its support in attaining our objectives.

To be more explicit, biology, compared with other branches of the natural sciences, has been most deficient in general theory. This has not resulted from the biologist's failure to recognize the need of general theory, but because living systems are so extremely complex that it has been difficult to produce anything more than the most general of concepts and to extend physical theory for a small space into the understanding of life. Secondly, there has been no large industrial segment developed as a component of the biological sciences as there has been in physics and chemistry. The state, therefore, of self-generated technology for biology is low. For that reason, this paper concerns mainly plans and identification of areas of interest, rather than solid accomplishments.

The overall goals of the Biosciences Program are; first, to extend our fundamental knowledge of biology using the conditions that are available from space transportation and, second, to utilize the knowledge of biological sciences that has been developed to extend our ability to explore space. In the field of biology, these goals fall primarily into two program areas: *environmental biology*, that is, extending our knowledge of the effects of environmental variables on earth organisms from microorganisms all the way to man; and *exobiology*, the investigation of extraterrestrial environments for life.

Figure 13–1 gives some examples of the kinds of studies in biology appropriate to the space sciences. The existing program may be discussed in terms of increasing complexity by presenting, first, two programs that are underway using high altitude balloons. (See fig. 13–2.)

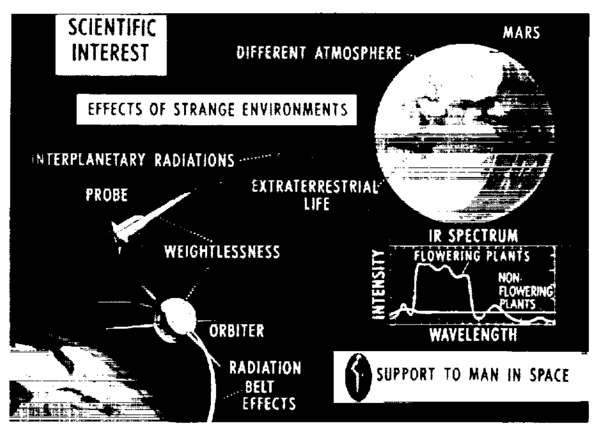
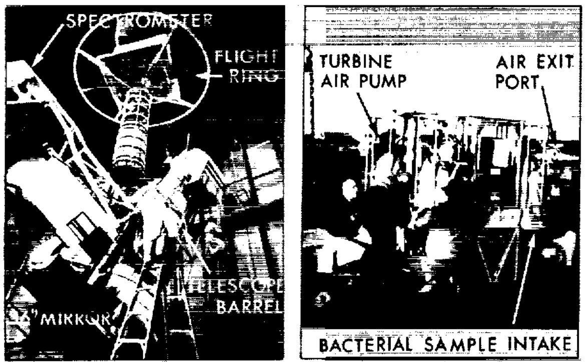


FIGURE 13–1.—Life in space.

Under NASA's sponsorship, there has been developed a high-altitude atmospheric sampler for the purpose of looking for microorganisms in the upper atmosphere. There have been two flights of this system. During a warm and



INFRARED SPECTRA OF THE PLANETS

STRATOSPHERE AIR SAMPLER

FIGURE 13-2.—Balloon borne observatories.

turbulent period in July 1962, large numbers of pigmented bacterial organisms were found at an altitude of 65,000 feet. However, during the second flight in October 1962, at the same altitude but under "polar air mass" meteorological conditions, very few organisms were found. It appears that the bacterial, fungal, and pollen content of our atmosphere, particularly our stratosphere, will vary greatly with meteorological conditions as does the gaseous composition of the atmosphere itself. The first of these flights shows results sufficiently striking that we are anxious to continue this series and find out more about the kinds of organisms that may be found at such high altitudes—what it is that allows them to exist under such unusual conditions and what the relationships are between these high-altitude microorganisms and those in the lower atmosphere. Another balloon project, a high-altitude infrared planetary observatory, has been completed, tested, and shipped to the National Scientific Balloon Center in Palestine, Tex. This is a 36-inch telescope with an infrared spectrophotometer which will be flown during the February 1963 apposition of Mars to obtain atmosphere-free spectra of that planet. In view of the great interest in Mars as a possible site for the discovery of extraterrestial life, we are eagerly awaiting the results of this balloon flight.

An attempt has been made to expose living organisms to the space environment with high-altitude probes. This attempt was the earlier Bios I program (fig. 13-3) which advanced our ability to design experiments for space considerably. Only in that respect, however, was the project a success because, unfortunately, the two probes that were launched were not recovered.

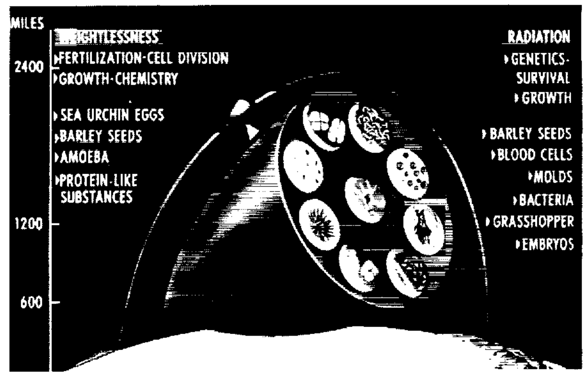


FIGURE 13-3.—Bios.

Closer study of the predicted reactions of living organisms to the space environment has convinced us that a much better approach is that of using a satellite for studies of environmental biology in space conditions near the earth. We are at present in the process of developing a satellite system which is adequate, both in terms of exposure conditions and in financial outlay, for doing a wide variety of biological experiments.

Figure 13-4 is a diagrammatic representation of the experimental situation in which we hope to learn more about the effects of the space environment on living organisms. We are, at this moment, wrestling with the problem of developing a system which will have the required parameters. These parameters include, for example: access to the experimental payload a very brief time before launch as well as very shortly after recovery; a trajectory which will allow a long time in orbit with a minimum of payload cost in terms of life support, power, and control mechanisms; a minimum of accel-

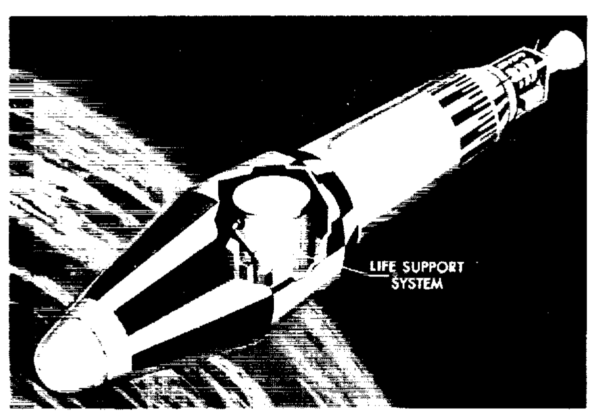


FIGURE 13-4.—Biosatellite.

eration developed by the control mechanism during the orbital period. For the first flights, the studies are directed primarily at weightlessness and removal from the earth's rotation.

The radiobiologists, with whom we are discussing this program, feel that the most important thing to do in terms of radiation effects, is to study radiation from a known source in the space environment to eliminate the possibility of synergistic effects between radiation and some other space variable, such as weightlessness, before going into study of the effects of space radiation itself.

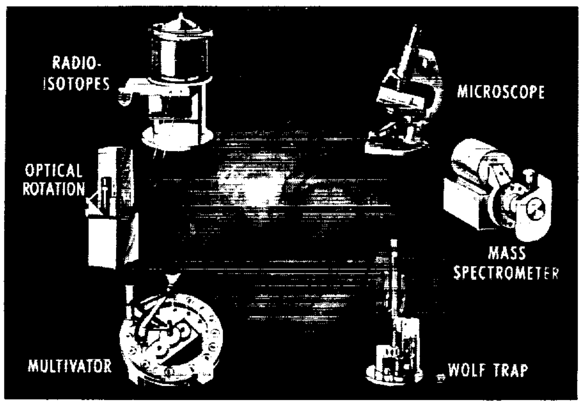


FIGURE 13-5.—Search for extraterrestrial life.

The search for extraterrestrial life (fig. 13-5) is undoubtedly the most intriguing part of the Bioscience Program and perhaps of all the space sciences. For the moment, until our technology allows us to get to the moon and planets with soft landings that will permit the conduct of experiments designed to establish the existence of life, we must be content with data such as can be obtained with spectroscopic measurements by telescopes and planetary fly-bys, examination of meteorites, and simulation of planetary environments to find out what the range of possibilities for living processes from among our own familiar earth forms may be. At the same time, however, we must be preparing for our opportunity to land experimental instruments on other planets, and we are now engaged in the process of developing extraterrestrial life detectors. This program calls for the greatest talent we can muster, both in terms of biological theory upon which such detectors may be based and of the technology itself for producing maximum reliability and miniaturization. Of the several life detectors that have been designed, one is practically in the state of flight readiness, and one or two others are near it.

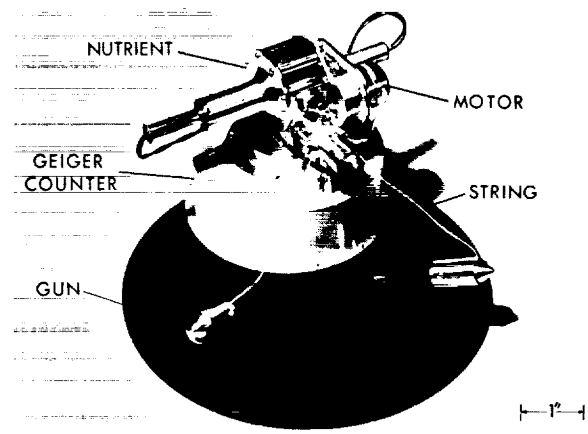


FIGURE 13-6.—Planetary life detector.

Figure 13-6 shows the reasonably well publicized "Gulliver", a device which operates on the basis of collection of a soil sample on a "sticky string" which is drawn into a culture medium containing radioactive carbon. Radioactive CO_2 is given off by the metabolism of organisms collected, and its rate of evolution is measured by a geiger counter. This is a remote life detector which is nearing its final configuration and has been successfully used in the field. The opportunity for landing a life detecting device on the Martian surface poses a severe challenge. (See fig. 13-7.) To be ready with adequate devices to ascertain whether life exists on that planet not only requires the development of suitable life detectors but demands a degree of sterility of the equipment landing on the planet not even

FIGURE 13-7.—Planetry surface sampling.

matched in today's medical procedures. The present policy calls for a probability of no more than one chance in ten thousand of landing a single living organism on the planet. This feat must be accomplished without degrading the reliability of the complex system required for accomplishing this mission.

These tasks call for the best that American industry and American biologists have to offer in talent *and* in cooperation.

14 Light and Medium Launch Vehicles and Propulsion

RICHARD B. MORRISON

Director, Launch Vehicles and Propulsion Programs, Office of Space Sciences

The Office of Launch Vehicles and Propulsion Programs of the Office of Space Sciences is responsible for the development and procurement of vehicles for the National Aeronautics and Space Administration unmanned space missions. The function of this Office assures that a family of vehicles capable of performing the many unmanned missions is available to the National Aeronautics and Space Administration as well as the other agencies charged with or interested in the execution of such space missions.

In order to carry out these functions in an effective manner, the launch vehicle staff is organized on a project basis. The project organizational breakdown of this group is shown in figure 14–1. The three Project Offices—Centaur, Agena, and Small Vehicles—embody the development and procurement of the Atlas-Centaur, Atlas-Agena, the Thor-Agena, the

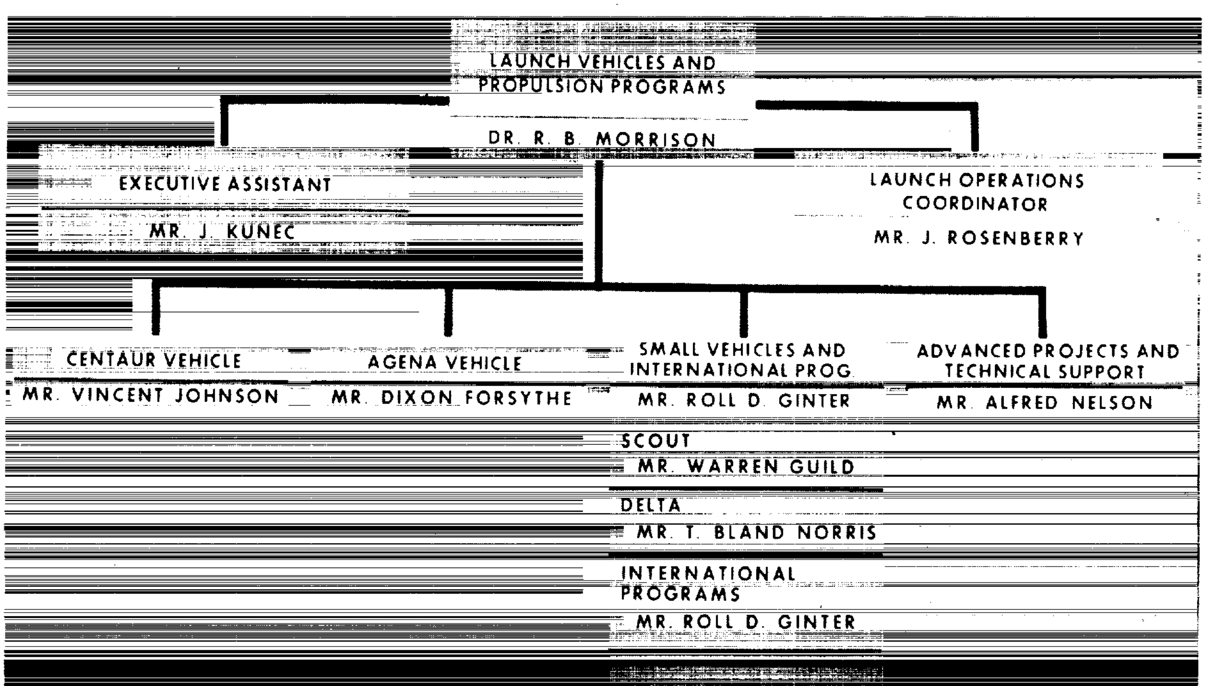


FIGURE 14–1.—Organization of Launch Vehicles and Propulsion Programs, Office of Space Sciences.

Thor-Delta, the Scout, and the Sounding Rocket Launch Vehicle Systems. The fourth Project Office of Advanced Projects and Propulsion Programs provides a technical and support service which was established to:

(a) Assure that launch vehicle capability is adequate to meet future mission requirements

(b) Explore means of reducing launch vehicle costs and increasing their reliability; that is, cost effectiveness

(c) Conduct a vehicle and propulsion technology effort to meet future light- and medium-class vehicle requirements

(d) Maintain close liaison and knowledge of advanced propulsion projects conducted by the Office of Advanced Research and Technology, including efforts on electric and nuclear propulsion projects

Technical responsibility and direction for light- and medium-class vehicles is maintained through the lead field centers shown in figure 14–2 and table 14–I. A recent transfer of the Centaur and Agena projects from the Marshall Space Flight Center to the Lewis Research Center was effected for the primary purpose of allowing Marshall Space Flight Center to concentrate on the high-priority project Saturn and to increase the technical effort on the Agena and Centaur. Major programs for the Saturn vehicle will be covered in subsequent papers.

It is NASA policy to depend primarily on contractors to perform the necessary hardware development, fabrication, and support of the light- and medium-class launch vehicles. Prime and major contractors that support this space vehicle program are given in table 14–II. The heavy dependence of NASA upon the missile manufacturers and their suppliers reflects the desire of the National Aeronautics and Space Administration to utilize to the utmost a large national investment in resources represented by these programs. The close cooperation with the Department of Defense is illustrated by the heavy reliance of NASA upon DOD for technical support, facilities, contracting, inspection services, auditing, procurement, and other functions so necessary for the proper management of complex launch vehicle systems.

Each of the light- and medium-class vehicles possesses a performance and cost that is uniquely reflected by mission requirements (fig. 14–3).

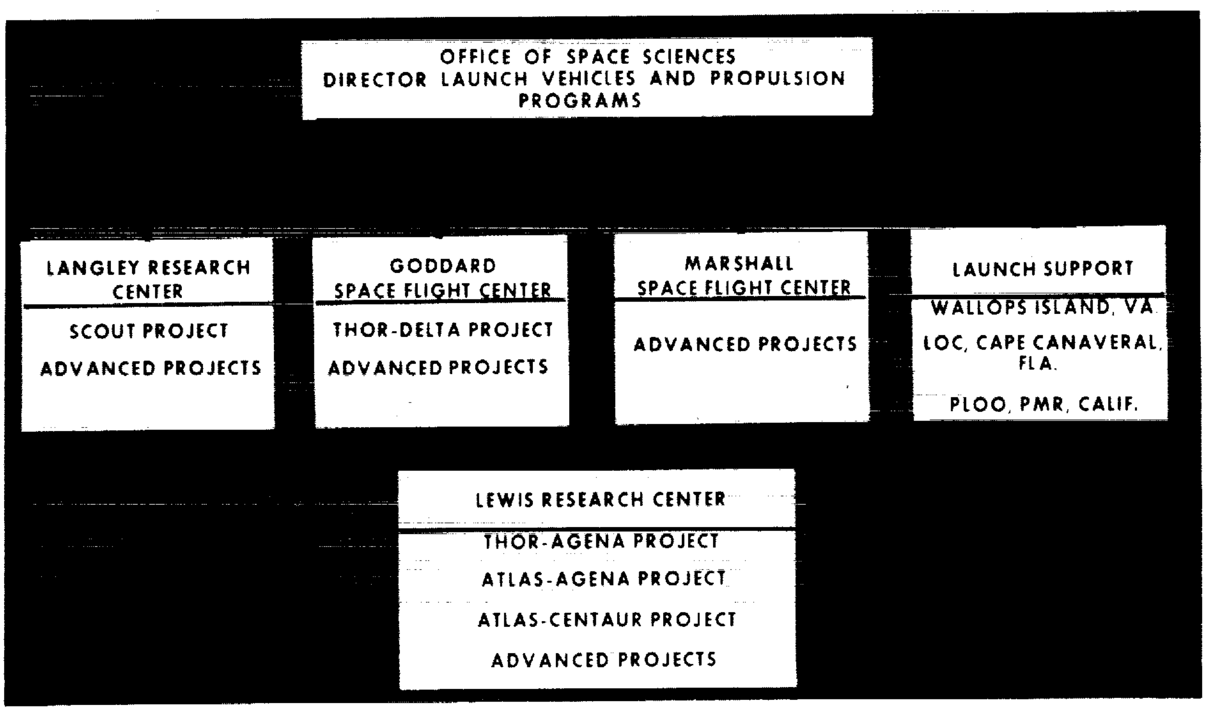


FIGURE 14–2.—Field centers technical direction, light and medium vehicles.

TABLE 14–I.—*Launch Vehicles and Propulsion Program Responsibility*

Project	NASA Headquarters Project Chief	Field Center and Industry Contact Project Manager
Scout	Mr. Warren Guild	Langley Research Center, Col. George Rupp
Delta	Mr. T. Bland Norris	Goddard Space Flight Center, Mr. William Schindler
Agena	Mr. Dixon Forsythe	Lewis Research Center, Dr. Seymore Himmel
Centaur	Mr. Vincent Johnson	Lewis Research Center, Mr. David Gabriel
Advanced projects	Mr. Alfred Nelson	

TABLE 14–II.—*Launch Vehicle Contractors*

Atlas-Centaur	Atlas-Agena	Thor-Agena	Delta	Scout
		Prime		
General Dynamics Pratt & Whitney	General Dynamics Lockheed	Douglas Lockheed	Douglas	Chance Vought
		Sub		
Bell Aerosystems Minneapolis-Honeywell Librascope Texas Instruments Borg-Warner—Pesco Products Div. General Electric	North American Aviation—Rocketdyne Div. General Electric Burroughs Bell Aerosystems Minneapolis-Honeywell	North American Aviation—Rocketdyne Div. Bell Telephone Lab. Minneapolis-Honeywell RCA	Aerojet-General Corp. North American Aviation—Rocketdyne Div. Bell Telephone Lab. Minneapolis-Honeywell Texas Instrument Corp. Electro-Solids Corp. Allegany Ballistics Lab.	Minneapolis-Honeywell Walter Kidde Aerojet-General Corp. Thiokol Allegany Ballistics Lab.

The brief discussion that follows illustrates to a degree specific vehicle accomplishments:

SCOUT

Scout, which is the smallest member of the basic NASA launch vehicle family, is a four-stage solid-propellant vehicle consisting of an Allegany Ballistics Laboratory Altair motor fourth stage which has a specific impulse of 256; a third stage ABL X-258 motor, specific impulse, 281; a second stage Thiokol Castor motor, specific impulse, 267; and a first stage Aerojet-General Algol motor, specific impulse, 222 (figs. 14–4 and 14–5). This program was initiated in late 1958 with the first launching on July 1, 1960. Through 1962, 15 Scouts have been launched, of which 9 have been completely successful. Launch complexes are located at Wallops Island on the east coast and Point Arguello on the west coast. They are in full operation to effect easterly or south polar

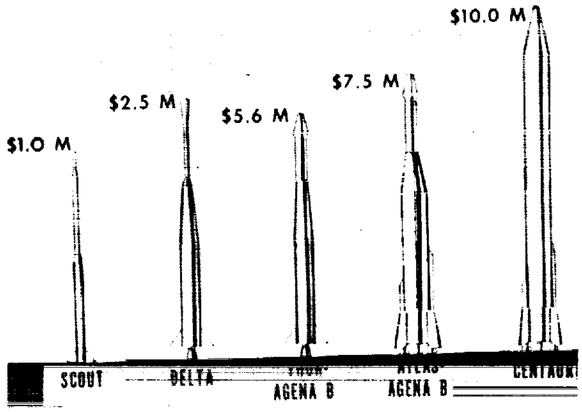


FIGURE 14-3.—Average cost, light and medium launch vehicles.

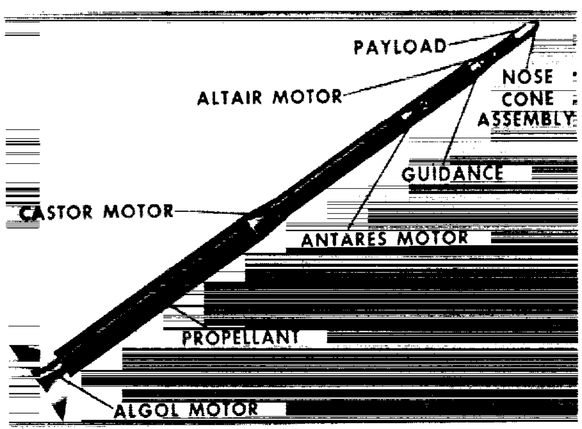


FIGURE 14-4.—Scout.

launches, respectively. A second launch complex for Wallops Island is presently under construction.

This vehicle is presently employed for small satellite missions, high altitude probes, and re-

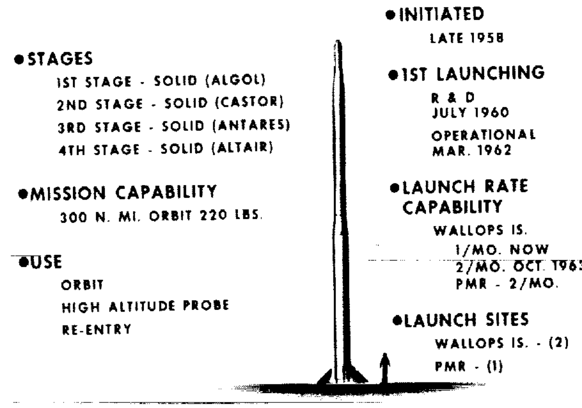


FIGURE 14-5.—Characteristics of Scout.

search experiments such as atmospheric reentry tests. Present Scout capability allows 220 pounds to be placed in a 300-nautical-mile orbit. This capability will be improved to 250 pounds very shortly. In addition to this performance gain, additional improvements will allow more precise injection parameters to be established.

A salient merit of the Scout is its low cost of approximately $1 million. It is also to be noted that Scout, an all solid propellant vehicle, employs the highest specific impulses used in operational vehicles. Its cost in terms of dollars per pound of initial gross weight is approximately the same as that for a larger vehicle: namely, a little over $20 per pound.

DELTA

Delta is a three-stage space launch vehicle consisting of a DM21 Thor liquid propellant first stage, a modified Vanguard liquid propellant second stage, and the X-248 spin stabilized solid propellant third stage (figs. 14-6 and 14-

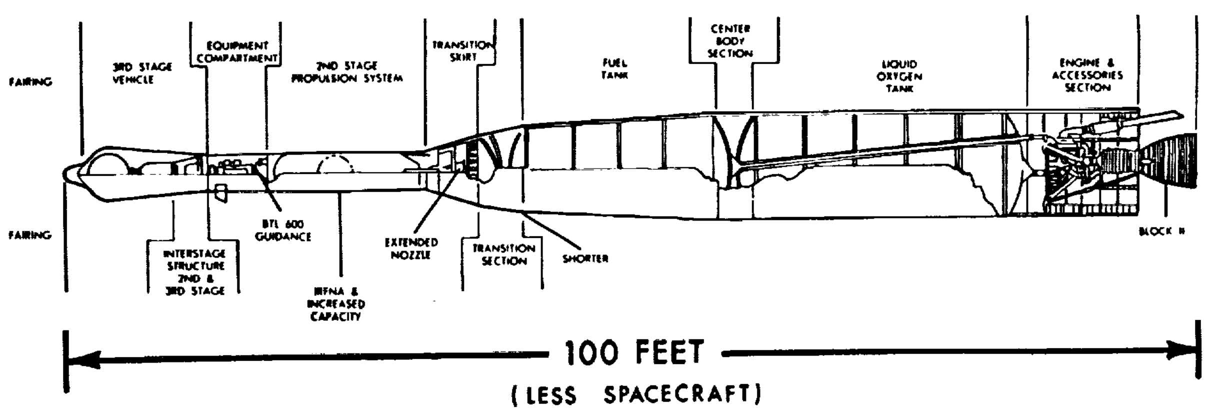


FIGURE 14-6.—Delta inboard profile.

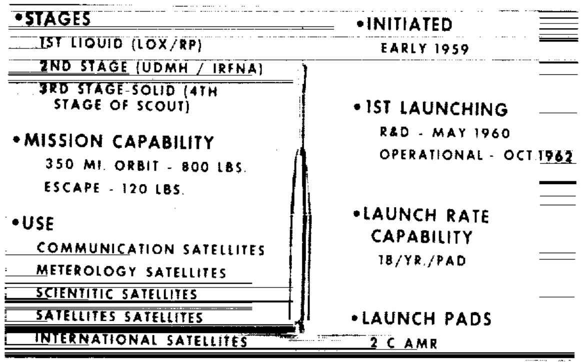


FIGURE 14-7.—Characteristics of Delta.

7). This program was initiated in early 1959 as an interim space research vehicle relying heavily upon the elements from the Vanguard and the Thor-Able programs. An initial development program was completed in September 1962 with the eleventh successive successful launch for a total of 11 out of 12 launches. A high reliability and a reasonable launch cost of \$2.5 million has extended indefinitely the planned Delta useful life. At present, approved and planned missions for Delta exceed 40. The improved version commencing with Delta 15 was successfully flown in December 1962. It can place 800 pounds in a 300-nautical-mile earth orbit and has an escape payload capability in excess of 100 pounds. Delta is launched from the Atlantic Missile Range from the old Thor development pads. The string of straight successes has been extended to 14 with only the first development launch failing to achieve a good orbit. Delta has earned an esteemed place in the national launch vehicle stable.

THOR-AGENA

The Thor-Agena launch vehicle which has been used so successfully by the U.S. Air Force consits of the Agena B and DM 21 Thor booster. About 50 percent of all U.S. satellites including those of the military have been orbited with this launch vehicle. This represents about 80 percent of the total U.S. space hardware by weight. NASA space missions to be met with the Thor-Agena include the Polar Orbiting Geophysical Observatory, the meteorological satellite Nimbus, and communications satellite Echo II.

The Canadian Topside Sounder, Alouette, was successfully launched on September 29, 1962, from the Pacific Missile Range to explore the ionosphere from above. All the Thor-Agena vehicles are presently planned to be launched from the Pacific Missile Range into polar or near-polar earth orbits. (See figs. 14–8 and 19–9.)

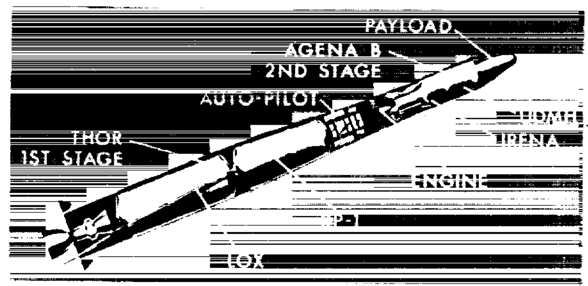


FIGURE 14-8.—Thor-Agena B.

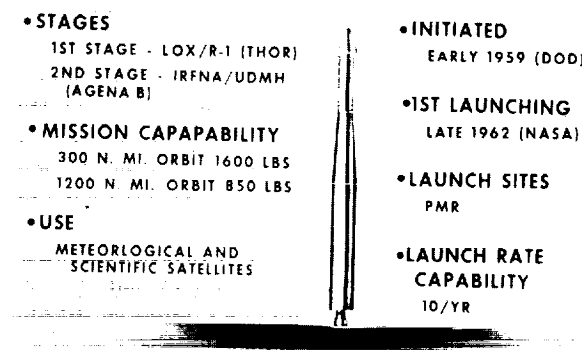


FIGURE 14-9.—Characteristics of Thor-Agena B.

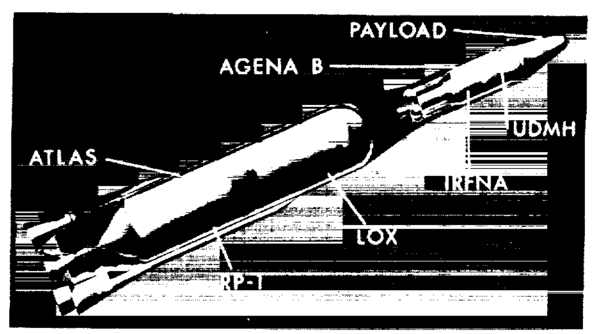


FIGURE. 14-10—Atlas-Agena B.

ATLAS-AGENA

The Atlas-Agena (figs. 14–10 and 14–11) uses the same upper stage as the Thor-Agena and an Atlas first stage. The Atlas is the same basic booster used so successfully in the Mercury program.

The common use of this vehicle by the Air Force and the National Aeronautics and Space

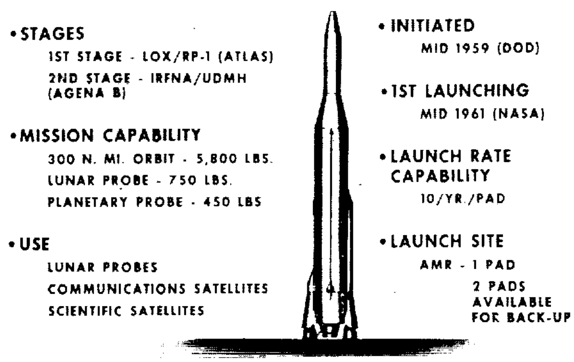


FIGURE 14-11.—Characteristics of Atlas-Agena B.

Administration provides for a larger number of launches which should eventually reflect in high reliability. Until the Centaur vehicle becomes operational, NASA will use the Atlas-Agena for early lunar exploration and planetary missions. The Atlas-Agena placed the Mariner on its fly-by trajectory to investigate the planet Venus. The Atlas-Agena vehicle will be employed to launch the heavier scientific satellites such as the geophysical observatories and the astronomical observatories. In addition, it will continue to be used in the Ranger lunar flights and the Mariner planetary flights. The Atlas-Agena is predominantly launched from the Atlantic Missile Range.

CENTAUR

The United States will employ Centaur (figs. 14–12 and 14–13) as the first practical application of a liquid-hydrogen, liquid-oxygen high energy upper stage. The first-stage booster is a modified Atlas launch vehicle with cylindrical tankage as required to mate with a 10-foot-diameter Centaur upper stage. The Centaur represents a very lightweight high performance

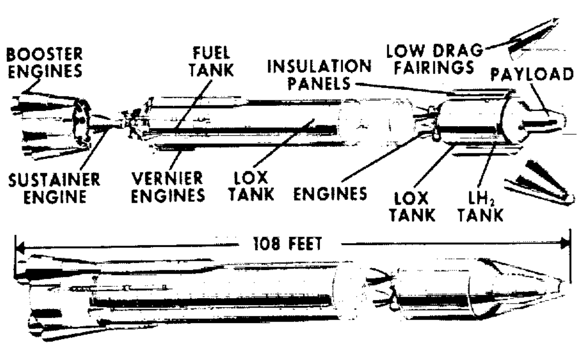


FIGURE. 14-12.—Centaur in-flight separation.

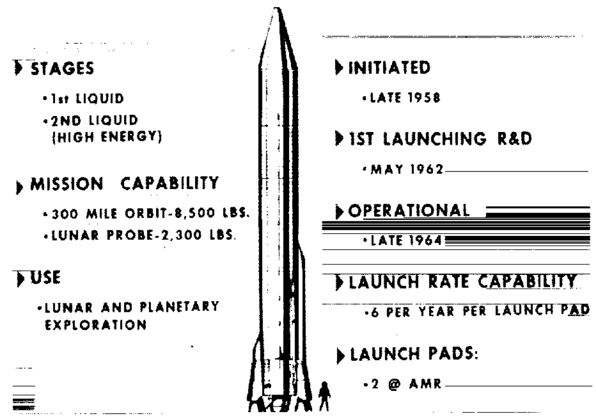


FIGURE 14-13.—Characteristics of Centaur.

upper stage exploiting the full potential of this high energy propellant combination. The requirement for high performance necessitated the development of a lightweight all inertial guidance system along with other special subsystems unique to the Centaur. Centaur will fly unmanned lunar and planetary exploration projects beyond the present capabilities of the Atlas-Agena launch vehicle. Other potential missions for Centaur include communications, meteorological, and scientific satellites in high earth orbits as well as high velocity interplanetary probes.

The next development flight is scheduled for mid-1963 with additional flight tests scheduled at regular intervals. This vehicle will be fully operational by late calendar year 1964 or early 1965.

CONCLUDING REMARKS

The National Aeronautics and Space Administration is expending approximately $250 million in fiscal year 1963 for the design, develop-

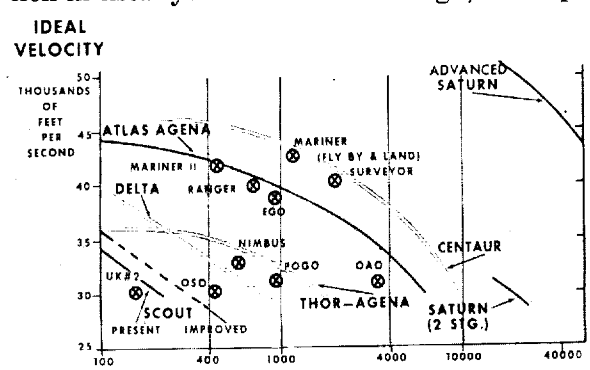


FIGURE 14-14.—Launch vehicle capability.

ment, and procurement of light- and medium-class vehicles below the Saturn class. Current planning in this decade reflects continuing expenditures for these types of vehicles in excess of $300 million per year.

Figure 14–14 illustrates the capabilities of our launch vehicles. It is to be expected that the future of light- and medium-class vehicles will be heavily influenced by their cost effectiveness, that is, increased performance at lower cost with higher reliability. To this end, standardized stages will be employed for existing vehicle combinations. The use of nuclear propulsion systems and/or electric propulsion systems for missions planned by the Office of Space Sciences is not foreseen before the middle of the next decade. High-energy chemical propulsion systems will, therefore, be the mainstay of our deep-space missions prior to that time. These high-energy chemical systems may well be cost effective for booster applications as well as for upper stage use.

15 The Role of Space Science Facilities

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The success of unmanned spacecraft, interplanetary probes, and their associated launching vehicles depends primarily upon two factors. The first is *sound* design and the second is *thorough proofing.* In figure 15–1 the complex and diverse performance requirements of the Office of Space Sciences (OSS) spacecraft and launching vehicles are illustrated by some examples. The utmost in reliability and long life in unique environmental situations in space, on the moon, and on the planets is sought. Various guidance, control, and command systems are utilized in the launching vehicles, the near-earth satellites, and the deep space and planetary probes. The enviroment imposes unique demands in temperature, pressure, radiation, magnetic fields, micrometeorites, and so forth, all of which must be accounted for in the basic design and proofing.

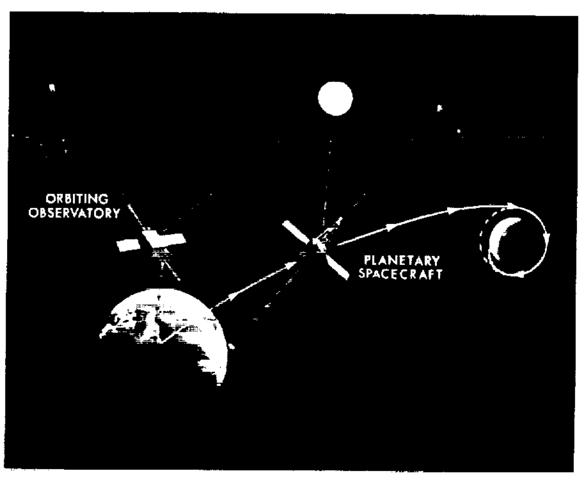

FIGURE 15–1.—Design environment.

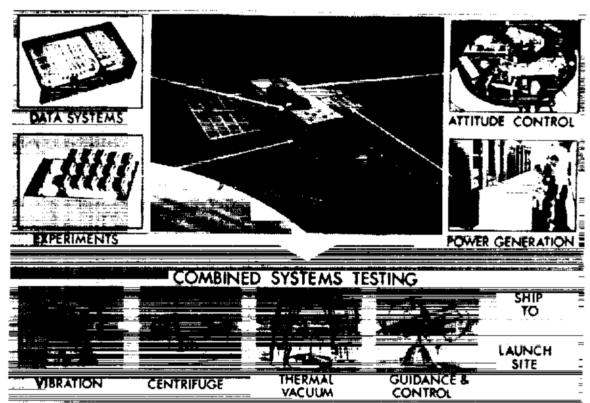

FIGURE 15–2.—Spacecraft evolution.

In figure 15–2 the fabrication and development of a satellite is indicated. In reviewing the role of ground-based facilities and their importance in insuring reliablity and long life, it is desirable to follow a spacecraft from the component stage through assembly, testing, launching, and data readout.

The components and subsystems must be thoroughly tested in order to eliminate poor performers and in order to insure superior design. Facilities for component and subassembly testing are of particular interest and importance. The vast majority of failures are found here.

After superior components and subassemblies have been selected, the satellite itself may be fabricated. Some of the various essential satellite testing facilities are indicated in figure 15–3. Other typical facilities are shown in figures 15–4 to 15–6. The complete satellite system is subjected to extensive tests. There are acceleration tests, vibration tests, thermal and vacuum tests, and, of very great importance, complete guidance and command tests in a simulated space environment. Table 15–I contains a summary of approved facilities, and their general characteristics are described in appendix A at the end of this paper.

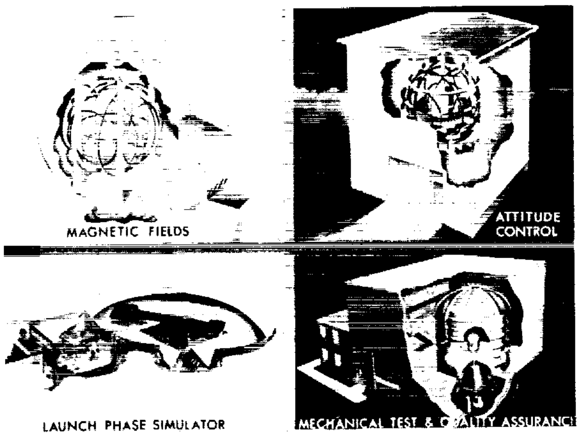

FIGURE 15–3.—Satellite testing facilities.

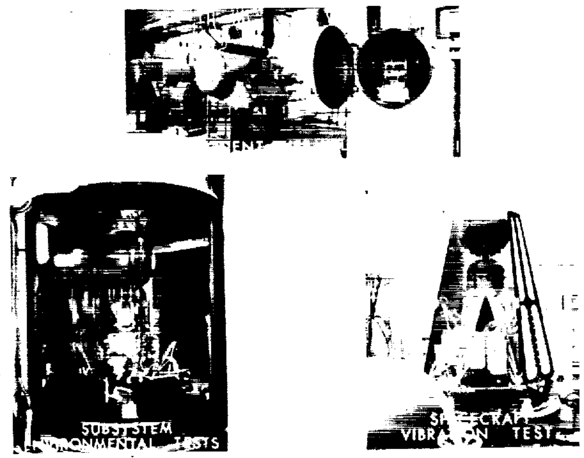

FIGURE 15–5.—Spacecraft development facilities, Jet Propulsion Laboratory.

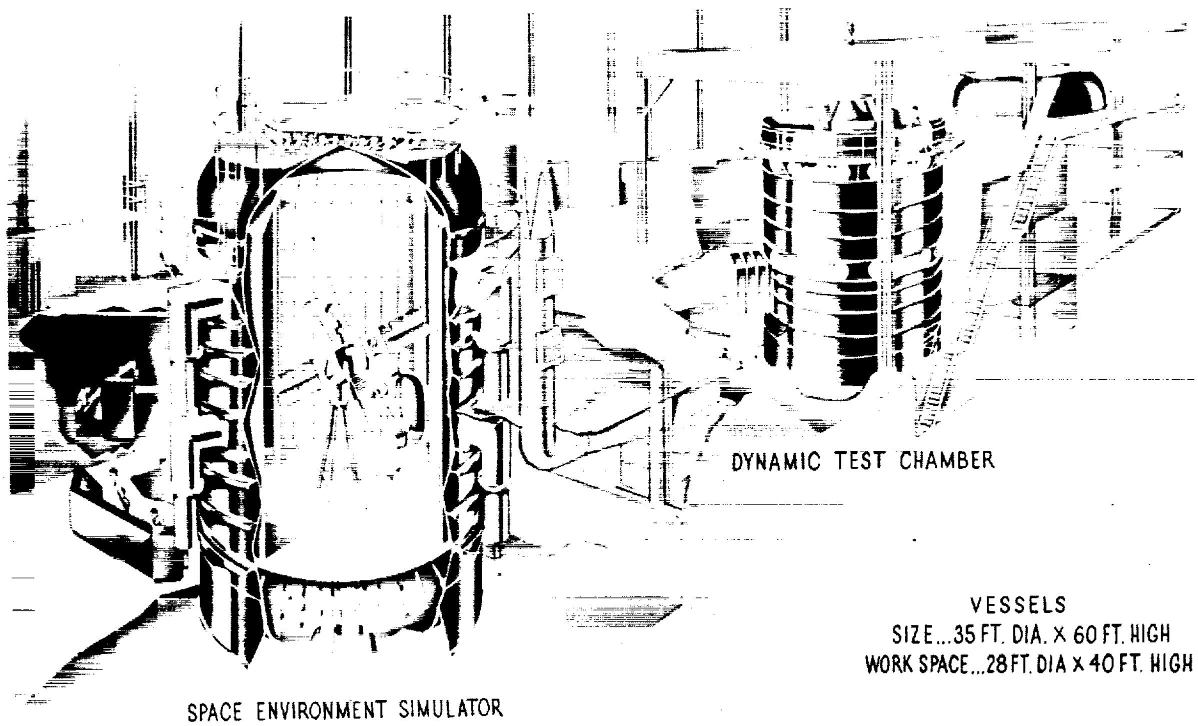

FIGURE 15–4.—Typical spacecraft development facilities.

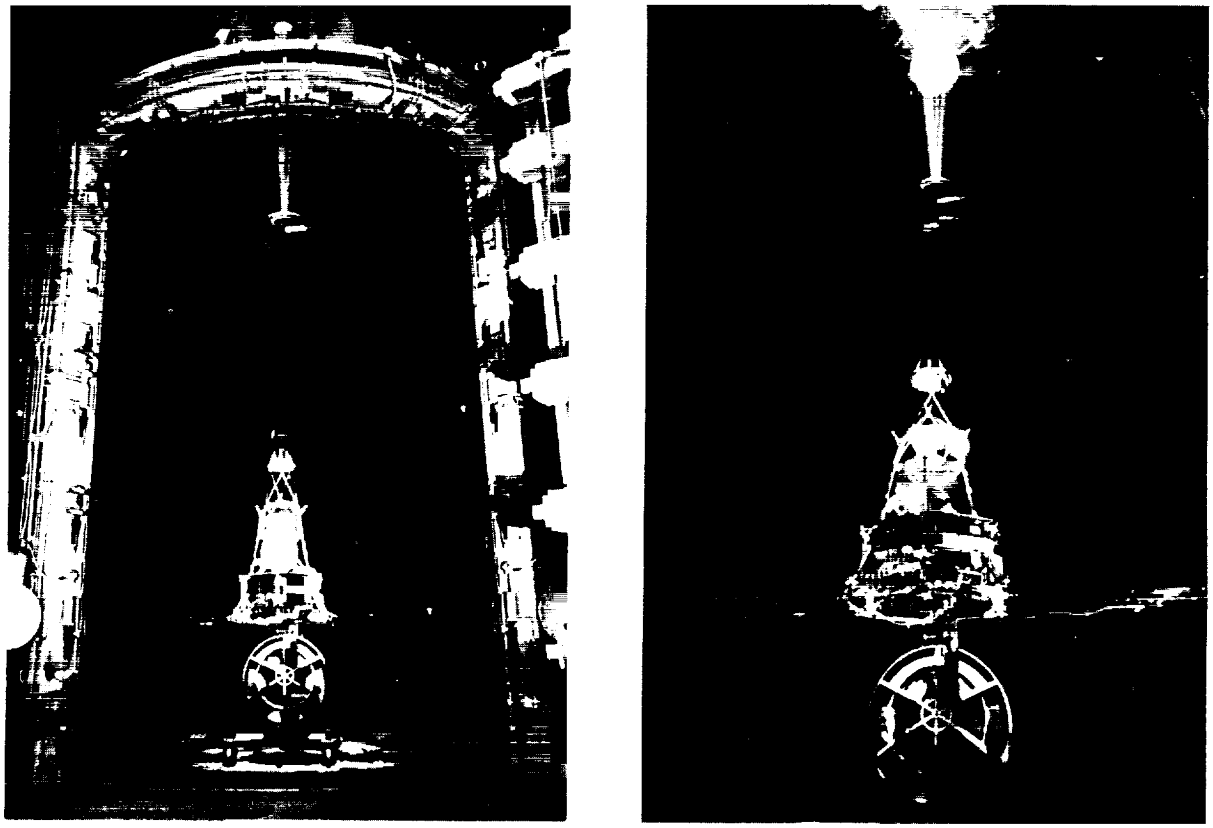

FIGURE 15-6.—Space environment simulator.

After the complete satellite has been thoroughly proofed at the Spacecraft Center or home facility of the industrial contractor, it is then shipped to the launching range. Figure 15-7 shows schematically the primary satellite facilities at the launching site. The satellite enters the prelaunch assembly and checkout building where it is readied for launching.

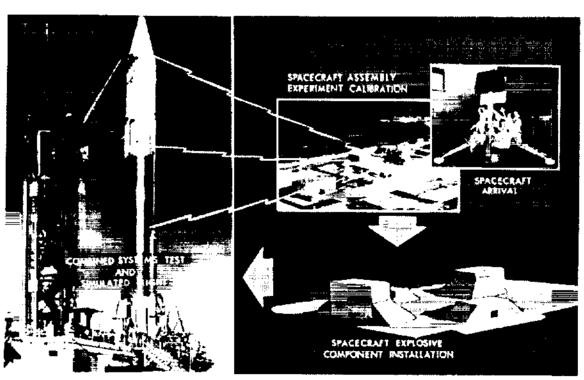

FIGURE 15-7.—Prelaunch assembly and checkout, Cape Canaveral, Fla.

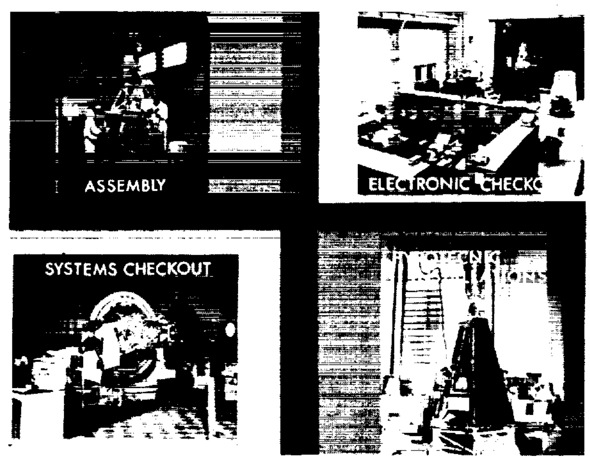

FIGURE 15-8.—Spacecraft preparation.

Some of these specific operations are illustrated in figure 15-8. The facilities include major assembly, static and dynamic balancing, electronic checkout, experiment calibration, installation of explosive ordnance, and monitoring of overall spacecraft system and experiment performance.

TABLE 15-1.—*Space Sciences Facilities Summary*

PROJECT	LOCATION	COST
Fiscal year 1961		
Space Environment Simulator	Jet Propulsion Laboratory	$4, 266, 000
Fiscal year 1962		
Unmanned Spacecraft Operations Facility	Launch Operations Center	801, 000
Centaur Launch Complex		18, 722, 000
Environmental Test Laboratory	Goddard Space Flight Center	7, 255, 000
Magnetic Fields Component Test Facility		1, 085, 000
Fiscal year 1963		
Biosciences Laboratory	Ames Research Center	870, 000
Unmanned Spacecraft Facilities	Launch Operations Center	2, 000, 000
Explosive Safe Assembly Facility		1, 160, 000
Modifications to Atlas-Agena Launch Complex No. 12		1, 188, 000
Attitude Control Test Facility	Goddard Space Flight Center	1, 387, 000
Conversion of Dynamic Test Chamber		2, 303, 000
Launch Phase Simulator		3, 915, 000
Space Flight Operations Facility	Jet Propulsion Laboratory	2, 415, 000

The launching vehicle also undergoes a similar history of design, assembly, testing, and checkout. (See figs. 15–9 to 15–11.) There are static tests of the rocket motor, guidance and command tests of an entire rocket upper stage, and many others.

In figure 15–12 the launch complex and its typical facilities are indicated; umbilical tower, communications lines, the blockhouse, tracking facility, and so forth.

Once the spacecraft is launched the real payoff operation begins. (See fig. 15–13.) The hub of activity is the Space Flight Operation and Command Center. The Center receives the signals from the spacecraft via the numerous tracking facilities and over various communication links. Some of the received data are immediately analyzed at the Space Flight Operations and Control Center to evaluate the overall performance of the spacecraft. Other data are channeled to the computing center and there are fed into the computing machine where the precise trajectory of the spacecraft is computed and where the in-flight systems and guidance performance of the spacecraft is determined. This performance is then reported back to the Operation and Control Center where corrective commands may be sent to the spacecraft in order to insure optimum performance in the determination of all desired scientific data. The varying conditions of the space environment resulting from sudden events which might be occurring on the sun or in the cosmos require constant monitoring, and new commands may be sent to the spacecraft. Also in the computing center, the various data from the scientific experiment telemetry are reduced and put into a form that can be sent to the many scientific principal investigators for their analyses.

The excellent performance of a Space Flight Operation and Control Center is exemplified by the one located at the Jet Propulsion Laboratory and, in particular, in its operations associated with the recent 109-day mission to Venus of the Mariner II. Several difficulties were encountered, many commands were given, and the mission was quite successful. It is by great detective work, continuous around the clock vig-

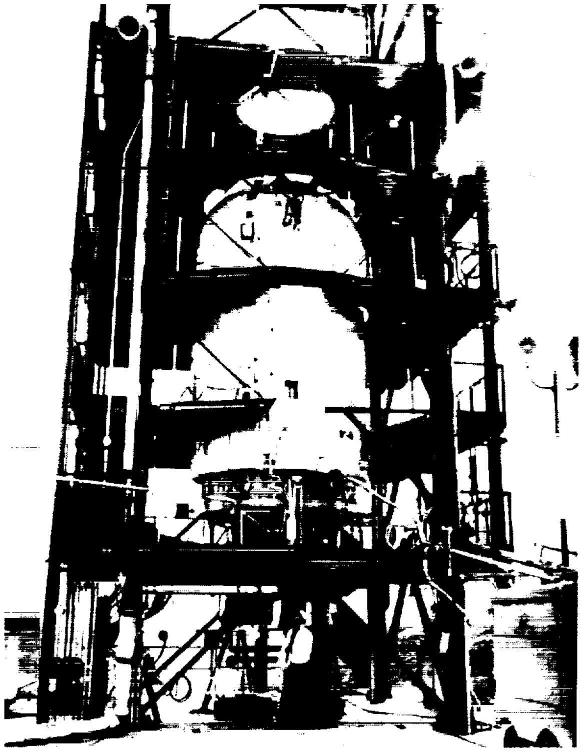

FIGURE 15-9.—Launch vehicle testing.

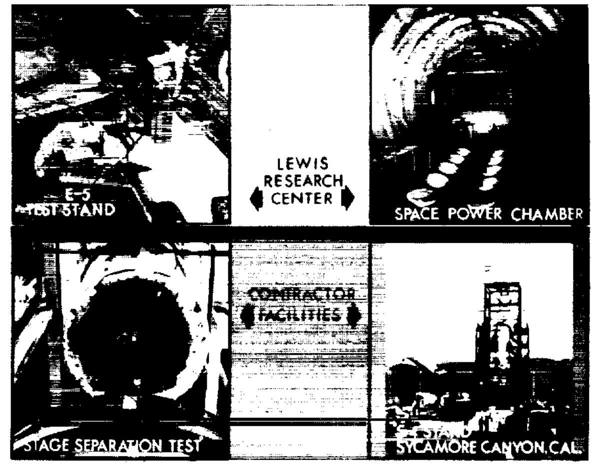

FIGURE 15-10.—Centaur development testing.

ilance, a thorough understanding of the spacecraft systems and their interactions, and the complete knowledge embodied in the Space Flight Operation and Control Center personnel that in-flight contingencies can be overcome.

Finally, to complete the story, the lead scientists on each experiment make their findings available to the world scientific community

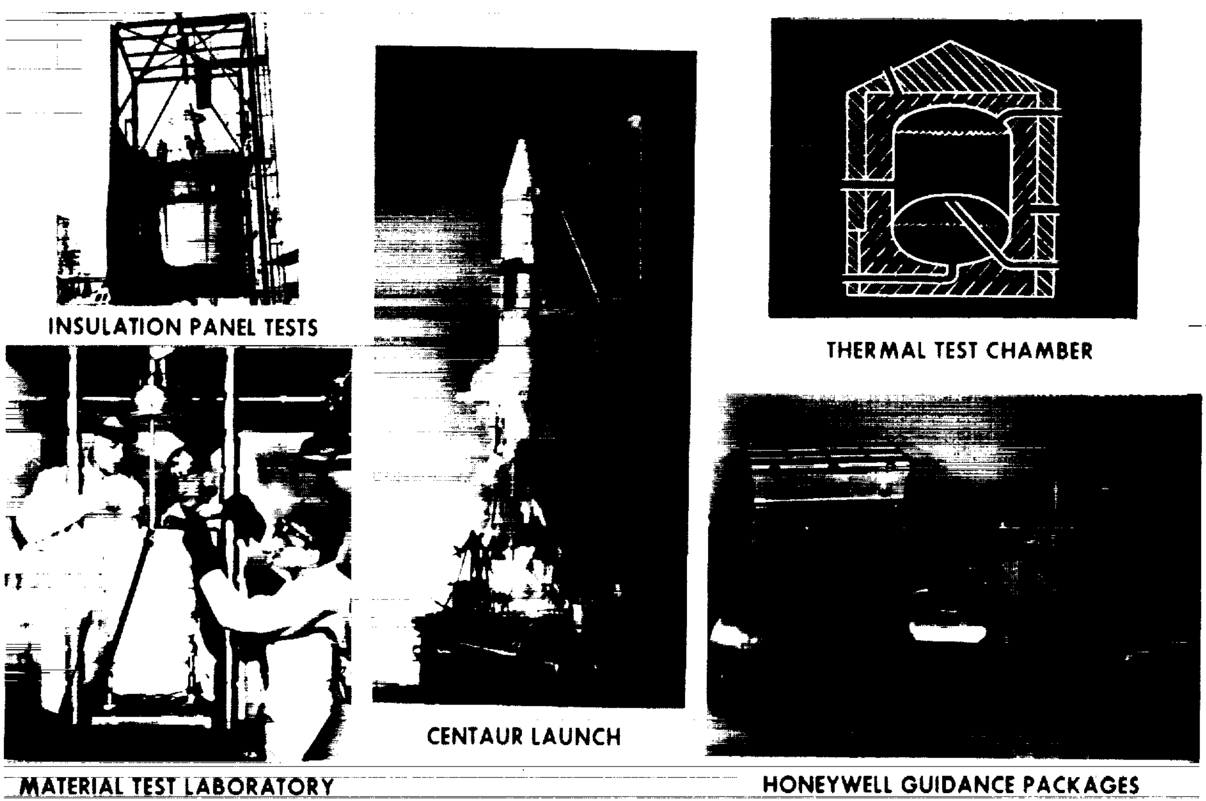

FIGURE 15-11.—Centaur special ground tests.

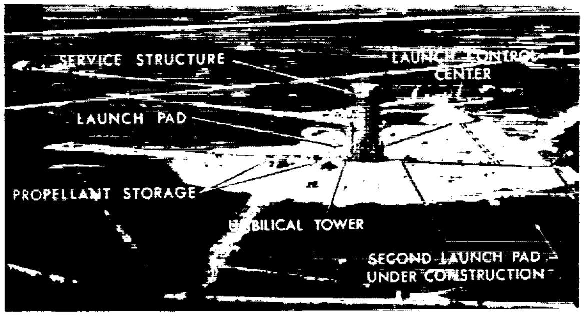

FIGURE 15-12.—Centaur launch complex, Cape Canaveral, Fla.

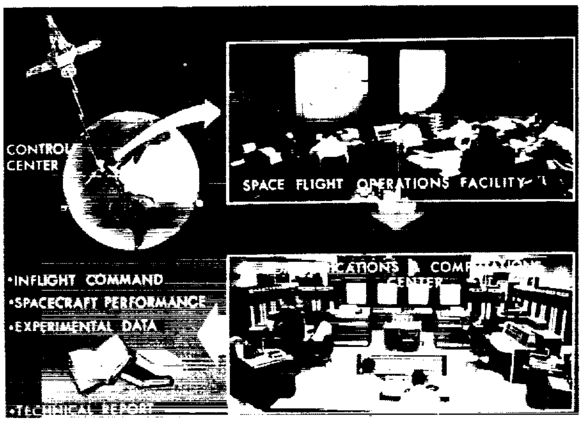

FIGURE 15-13.—Space flight operations.

through papers published in the open literature. Also, the project manager prepares a final report on the overall engineering performance of the spacecraft and launch vehicle in satisfying their mission objectives.

Some of the typical facilities required to proof-test the basic design of the satellite, its components, and its subsystems have been indicated. The spacecraft missions that have been carried out thus far range all the way from the simple Explorer type satellites to the complex and elegant Mariner II probe and the OSO satellite which performed complete guidance and control for over a year. Future science requirements indicate larger and more complex unmanned spacecraft and larger launch vehicles in the Saturn class (fig. 115-14). In terms of technology, missions such as soft landings and orbits of the moon and flights to planets are within reach in the next few years. Primary concern, however, will continue to be that of *sound basic design* and *thorough and complete proofing* of all components, all subsystems, and of the complete spacecraft and launching vehicle. (See fig. 15-15.)

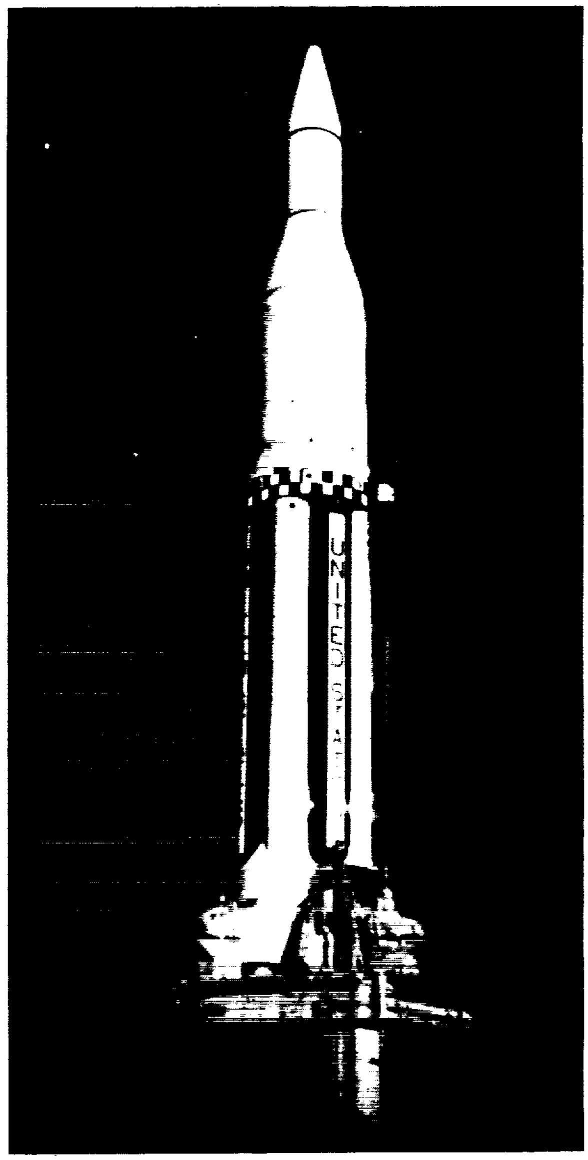

FIGURE 15-14.—Saturn.

It is clear that many types of facilities are required. Some of these facilities are needed at the home laboratories of the industrial contractor. Some of the very large facilities will have to be financed solely by the Government. (See table 15-II and appendix B.)

Certainly, in facing the challenge of the future an even greater and more cooperative team effort will be required to insure the continuing success of space sciences flight projects.

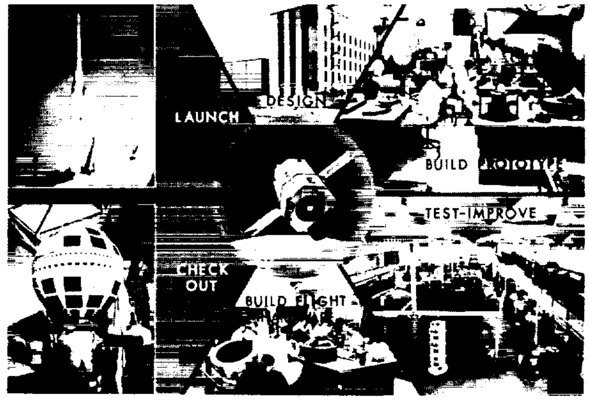

FIGURE 15-15.—Photographs taken at Goddard Space Flight Center.

TABLE 15-II.—*Construction of Facilities, FY 1964 Budget*

PROJECT	LOCATION	AMOUNT
Mechanical Test Facility and Quality Assurance Laboratory.	Goddard Space Flight Center	$5, 700, 000
Data Interpretation Laboratory	Goddard Space Flight Center	5, 390, 000
Modernization of Payload Test Facility	Goddard Space Flight Center	2, 500, 000
Utility Installations	Goddard Space Flight Center	2, 439, 000
Isolated Hazardous Test Facility	Goddard Space Flight Center	800, 000
Development Engineering Building	Jet Propulsion Laboratory	3, 900, 000
Addition to the Space Flight Operations Facility	Jet Propulsion Laboratory	1, 000, 000
Utility Installations	Jet Propulsion Laboratory	467, 000
Materiel Services Building	Jet Propulsion Laboratory	1, 633, 000
Unmanned Satellite Operations Facility	Atlantic Missile Range	1, 680, 000
Total		25, 509, 000

APPENDIX A

Characteristics of Approved Facilities (See Table 15-I)

SPACE ENVIRONMENT SIMULATOR (JPL)

This project provides for the construction of a test and research facility capable of simulating the vacuum and cold of the space environment. The basic unit is a 27- by 52-foot vertical vacuum cylinder built of ¾-inch stainless steel. The chamber contains a 25-foot-diameter spherical test volume, a space free of any obstruction in which the spacecraft or component under test can operate. The primary access door is 25 feet high by 15 feet wide. The chamber operates at pressures down to 10^{-6} millimeters of mercury, a vacuum sufficiently high to simulate space conditions for complete spacecraft proof test. The wall lining, cooled by circulating liquid nitrogen, maintains a temperature of approximately -300° F simulating the "heat sink" of outer space. A warmup system for this wall lining permits access to the test specimen upon completion of a test.

As space missions become more complex, each spacecraft reflects an ever larger investment. This investment makes it imperative that every attempt is made to insure a successful flight with each spacecraft. These large and complex structures must be capable, for example, of operating without failure during a 6-month transit to a planetary distance and then of continuing to collect, sort, and transmit data for another 6 months. The mission is successful only if every component and subsystem operates at its design value. Such a high degree of reliability requires thorough component and system testing prior to flight, particularly since opportunities for planetary missions are limited to about one per year (because of the long time of flight) and the necessity for a repeat attempt cannot be determined until long after a particular opportunity is past. A critical test that at present cannot be performed is to subject the entire spacecraft, under laboratory conditions, to the vacuum environment it will encounter in space for at least as long a time as it will be required to operate in that environment. Two heat sources affect a spacecraft: the sun and the internal power supplies. In the vacuum of space, such heat can only be moved along internal conductive heat paths and can only be dissipated by radiation. This is simulated by the radiation of spacecraft heat to the cold wall of the cylinder. It is of critical importance to test an entire operating spacecraft to insure that the delicate heat balance required by the instruments and components is maintained; too much or too little heat at a specific point can cause a complete system failure. The effect of hard vacuum itself on components, on the friction of moving mechanisms, and on the materials of the spacecraft differs in each case; only by testing the entire spacecraft under these conditions can an acceptable degree of reliability be built into each mission.

Unmanned Spacecraft Operations Facility (LOC)

This project will consist of the design and construction of an engineering laboratory building 100 feet by 202 feet. The building will consist of an 8,568-square-foot high-bay area surrounded on three sides by a one-story engineering office and laboratory area. The total gross floor area is 20,200 square feet. The facility will provide the necessary working space for the preflight preparation, testing, and final assembly of unmanned spacecraft under closely controlled environments of temperature, humidity, pressure, fungus and spore free ambients, and radiation to permit close calibration of engineering test and scientific instrumentation under simulated space flight conditions.

Centaur Launch Complex (LOC)

This project provides for the construction of a new launch pad, identified as Pad 36B, which will be incorporated into the existing launch complex No. 36 in completion of a dual-pad single-blockhouse concept. The new launch pad will consist of the launch stand (pad and pedestal), service tower, umbilical mast, propellant loading system, cableway to blockhouse, and the associated equipment providing launch capability for the Centaur vehicle. It will support both Department of Defense and NASA Programs.

Environmental Test Laboratory (GSFC)

This project provides the required building, facilities, and research equipment for final checkout and test of large spacecraft. These spacecraft are typical of the family launched by the Agena and Centaur vehicles, such as the Orbiting Geophysical Observatory and the Orbiting Astronomical Observatory. In the space environment with solar paddles extended, the maximum dimension of such spacecraft may be in the range of 20 to 25 feet and have weights that may range from 4,000 to 8,000 pounds. These spacecraft typically have large solar paddle arrays which are unfolded and extended after the protective nose shroud has been released and ejected in the space vacuum. Also, the final stage vehicle has start and stop capability producing accelerations in the space environments. This project includes two principal facilities: namely (a) a Dynamic Test Chamber in which the mechanical effects of the atmosphere are eliminated, and (b) a Space Simulator which includes the effect of solar radiation and the coldness of outer space in combination with the vacuum environment. The building structure will provide space for spacecraft checkout and monitoring equipment and will also house the two vacuum chambers.

Magnetic Fields Component Test Facility (GSFC)

The Magnetic Fields Component Test Facility will provide Goddard with one small, functional laboratory comprising two buildings, four sheltered concrete pads, access roads, and utilities for component tests and instrument development. Research equipment in the Magnetic Instruments Test Laboratory building includes a spherical coil-system 20 feet in diameter. A 5-foot-diameter nonmagnetic thermal vacuum chamber 5 feet in length will be located inside the coil system to provide vacua to 10^{-4} mm Hg and temperatures in the range from −65° to ±100° C. An overhead hoist will facilitate opening of the vessel and its complete removal when necessary.

The Magnetic Fields Component Test Facility will provide capability to simulate the effects on magnetometers of relative motion by the spin employed for stabilization in flight. The thermal capability will expedite development of advanced magnetic instruments by permitting quantitative measurements of thermal effects on performance in simulated space magnetic environments. Vacuum to 10^{-4} mm Hg will permit determination and correction of the thermal balance for optimum performance of instruments in the space magnetic environment and in the absence of atmospheric air convection heat transfer. The range of fields produced will provide capability to measure and extend the dynamic range of magnetic instruments.

Biosciences Laboratory (Ames)

A biosciences laboratory is proposed for construction to provide the research facilities, offices, and support functions for systemic and subsystemic research in the separate but related fields of immunology and genetics, radiobiology, and exobiology. Life sciences, from the space point of view, comprise the functions involved in the basic biological exploration of space and those aerospace medicine activities required for manned space flight. The proposed facility is necessary to permit a modest in-house capability to be acquired in the area of space biology similar to the manner in which in-house capability has been provided for other scientific disciplines in the physical and engineering sciences.

Additions to Unmanned Spacecraft Operations Facility (LOC)

This project provides for the design and construction of an addition to the existing Spacecraft Assembly building and a new two-story Engineering and Laboratory building with an integrated high-bay checkout and assembly area. Construction for the Engineering and Laboratory portions of the new building will be reinforced concrete with masonry curtain walls. The high-bay area will be of steel frame construction, with masonry and/or asbestos siding for the curtain walls. Two 15-ton bridge cranes, each having a hook height of 45 feet, will be provided in the high-bay area for the handling of spacecraft. Plan dimensions of the building are 178 feet wide by 155 feet deep. Provisions must be made for the simultaneous preparation of as many as four space vehicles with the additional possible requirement of providing backup vehicles. Longer preparation times plus overlapping launching schedules for lunar and planetary missions will create a requirement for overlapping payload preparation and checkout.

EXPLOSIVE SAFE ASSEMBLY FACILITY FOR UNMANNED SPACECRAFT (LOC)

This project provides for the design, construction, and equipping of a new Explosive Safe Facility. This facility will be used for the final assembly, dynamic and static balancing tests, and sterilization of large unmanned spacecraft. More specifically, this project will provide a Propulsion Laboratory of 1,680 square feet of gross floor area to be utilized for the checkout, loading, and pressurizing of the storable liquid propellant motors for spacecraft. Additional functions to be performed in this laboratory will involve assembly, checkout and dynamic balancing of the solid propellant motors. The building will be of reinforced concrete design and revetted as required to afford blast protection. The area will be equipped with the necessary test, balance, and fueling equipment and will provide for the protection of personnel against toxic propellants. An Instrumentation Laboratory will provide the necessary facility to house electronic instrumentation racks, consoles, and engineering space. The building will be constructed of reinforced concrete and revetted to afford blast protection, as required. This laboratory will be separated from the other laboratories to provide maximum protection of personnel during test phases, and to provide for protection of records, and so forth, in case of an explosion. The building will be air conditioned.

MODIFICATIONS TO ATLAS-AGENA LAUNCH COMPLEX No. 12 (LOC)

This project provides for the design, modifications, and construction necessary to increase the launch capabilities of existing Atlas-Agena facilities at Launch Complex No. 12 and to eliminate certain potentially hazardous service tower deficiencies. The total project task will consist of three separate and distinct phases: Phase I—Accomplishing the design and modifications necessary to adapt the service tower for Elliptical Orbiting Geological Observatory (EOGO) and Orbiting Astronomical Observatory (OAO) launchings. Modifications will include raising the bridge crane to provide increased hook height, providing additional platform working area above Tower Station (TS) 107, relocating and adapting existing platforms and decks as required, and providing a conditional environmental enclosure at TS-107; Phase II-Accomplishing the design and modifications necessary to strengthen joints and structural members of the service tower from the drive trucks to TS-107 so that it will withstand hurricane winds of velocities up to 120 miles per hour; Phase III-Accomplishing the design and modifications of the trucks, propulsion drive, and traction system necessary to enable the transfer table-service tower to travel against winds having velocities of 48 miles per hour. Also included in this phase are the design and construction of a tie-down pad on which the service structure can be effectively secured to withstand the force of hurricane winds.

ATTITUDE CONTROL TEST FACILITY (GSFC)

This facility will provide the Goddard Center with a functional attitude control laboratory comprising two buildings, four enclosed concrete pads, access roads, and utilities for testing complete spacecraft up to the size of the Orbiting Astronomical Observatory. The coil building will be of frame construction, 60 by 60 by 60 feet on a concrete foundation with all materials selected for nonmagnetic properties. Techniques for attitude control and space navigation which are either deliberately or unavoidably influenced by magnetic effects must be developed and refined. The proposed facility is required for the evaluation of the attitude control characteristics of scientific spacecraft. Meteorological satellites; geophysical, solar, and astronomical observatories; space probes; and other programs will benefit from the following capabilities to be provided by this facility: (a) Measurement of the magnetic signature of large, flight configuration spacecraft. This feature will be unique in the proposed facility with regard to the size of payload that can be mapped and to the precision of measurements that can be made; (b) Calibration of instruments over all ranges of interest when mounted in flight orientation within the influence of spacecraft induced fields; (c) Electrical rotation of the field about a stationary spacecraft to permit evaluation of magnetic spin damping torques without the use of a large vacuum vessel and special air bearings; (d) Electrical spin simulation to permit measurement and correction of the magnetic moment which causes precession and mutation of spin-stabilized spacecraft and guidance devices.

CONVERSION OF DYNAMIC TEST CHAMBER (GSFC)

This project proposes the conversion of the Dynamic Test Chamber to a Space Simulator. In order to effect the conversion, it will be necessary to clean the chamber and add liquid nitrogen cooled curtain walls within the vessel to provide programed wall temperatures between $-173°$ C and $+100°$ C. The vacuum system will be extended by the addition of diffusion pumps with baffles, and will increase the present vacuum from 0.1 mm Hg to 1×10^{-8} mm Hg. Additional stages of mechanical pumping will be added to existing pumps. Helium panels will be installed to complete the vacuum system. The existing substation will be modified to provide 1,000 kilowatts of additional power. The present design of the Dynamic Test Chamber provides a facility of limited capabilities. The intention of this project is to upgrade the existing facility to provide an extended range of test capabilities. The new capabilities will include: means for developing an ultimate vacuum of better than 1×10^{-8} large condensable and noncondensable gas loads from reaction jets while maintaining a vacuum of 5×10^{-5} torr; means for providing a uniform boundary temperature which is continuously controllable between 100° K and 373° K; means for measuring the vacuum at any location and in any direction both outside and within the spacecraft depending on the limitations of the spacecraft itself.

The facility will permit the testing of spacecraft in a simulated space environment excluding solar simulation, where precise thermal balance studies can be accomplished. Based on the present concept of space environment testing, solar simulation is not required during the total testing program. However, precise boundary temperature for high vacuum are required. The upgrading of this facility will give Goddard Space Flight Center sufficient Thermal-Vacuum capability to fulfill the projected program requirements of the OGO and other spacecraft of this class. In addition to the thermal testing, dynamic tests such as balancing, spin, and solar paddle erection will still be performed in this facility.

LAUNCH PHASE SIMULATOR (GSFC)

This project provides for the construction of a combined environment facility to be employed in the test and qualification of scientific unmanned spacecraft. The facility will be capable of subjecting spacecraft of the Centaur class and smaller to realistic simulation of the significant temperature and acceleration vacuum. The facility will comprise a test capsule mounted on a 60-foot-radius rotating arm, a prime mover system, related environmental systems and support equipment, and an operations building. Spacecraft will be mounted within the test capsule and subjected to steady-state acceleration loads resulting from centrifugal action as the arm rotates. The length of the arm is dictated by the size of spacecraft to be tested in the facility and by the maximum acceleration gradient produced along the thrust axis of the spacecraft under test that is consistent with realistic testing. It will be possible to test specimens 10 feet in diameter and 15 feet in length with an acceleration gradient of 20 percent. The facility will furnish an acceleration of 30 g for spacecraft weighing up to 100 pounds and 10 g for spacecraft of 4,000 pounds and less. Vibratory excitation will be imposed simultaneously with steady-state acceleration by means of an electronically controlled vibration shaker system with the vibration shaker located near the outboard end of the capsule at the spacecraft mounting interface. The test capsule will serve the dual purpose of a vacuum vessel and a streamlined aerodynamic shroud. Its design will eliminate transverse wind loads on the specimen and minimize the power required to overcome aerodynamic drag. A vacuum of 10^{-2} mm Hg will be achieved within the test capsule for combined environment tests and to eliminate mechanical effects of the atmosphere on spacecraft under test. High-performance mechanical vacuum pumps will be employed for evacuation. The test capsule will be designed to accommodate interior mounting of radiant heating and cooling elements for use when test programs require simulation of the temperature environment encountered during launch.

SPACE FLIGHT OPERATIONS FACILITY (JPL)

This building will provide the facilities for the computers and operation and control centers required for the Lunar and Planetary Programs. This facility will be of permanent steel or concrete construction and completely air conditioned. It will be designed to house analog and digital computers, maintenance area, supporting laboratories, engineering and scientific display and analysis areas, status plotting board, operations areas, communications center, and exhibit areas. It will also contain conference rooms and offices for the technical personnel engaged in the above work. The first floor will house the main data operations and control areas, communications and DSIF control rooms, space sciences area, customer engineering area, spacecraft analysis area, data conversion area, conference rooms, control lobby, restrooms, and TV display room.

APPENDIX B

Construction of Facilities (See Table 15–II)

MECHANICAL TEST FACILITY AND QUALITY ASSURANCE LABORATORY (GSFC)

This project will consist of approximately 60,000 square feet of laboratory space and is designed to accommodate 120 personnel engaged in technical support of flight projects. This facility will provide capabilities for evaluating dynamic mechanical functions of spacecraft and spacecraft systems. It will house a test chamber (40 feet in diameter, 30 feet high), its support equipment, and its operating control station. Included in the project is the equipment required for the Failure Analysis and Calibration Laboratories and for functional testing in the Mechanical Test Chamber.

This laboratory is required to provide capabilities for the quality assurance functions in support of Goddard's in-house and contracted design-development-fabrication activities.

DATA INTERPRETATION LABORATORY (GSFC)

This project will provide about 135,000 square feet of office and laboratory space for 400 scientific personnel engaged in tracking and data processing work. The building will be similar to Building 3 in construction. This laboratory will house data processing and telemetry equipment costing approximately $1.3 million.

This facility is required in order to provide an integrated data laboratory for operational data analysis and processing, development of advanced data processing systems, and the coordinated development and analysis of future aerospace telemetry and control data systems. By having all these functions in one building, it will be possible to tie together efficiently the developments and operations of the entire satellite-ground data systems.

MODERNIZATION OF PAYLOAD TEST FACILITY (GSFC)

This project provides for the modernization of the equipment in the Payload Test Facility. It entails the expansion of the centralized data collection and analysis system; increasing the capability of the 12- x 15-foot thermal vacuum chamber by adding solar simulation; replacement of obsolescent vibration equipment and instrumentation; and expanding the capability of the mechanical determination equipment by increasing its capability to handle larger spacecraft.

A high rate of obsolescence of equipment and techniques develops as facilities become operational and as experience grows. Modernization is needed for adequate testing of the larger and more complex spacecraft now being flown and being developed for future missions.

Utility Installations (GSFC)

This project will provide for the expansion of the utility installations to include an addition to the Central Power Plant to accomodate the fiscal year 1964 building program. It will also provide for the underground installation of the present 33-kilovolt power line. This will enable Goddard to use and develop effectively existing and future facility sites in the areas traversed by the existing overhead primary feeder system. Also included is the provision for a Goddard interchange with the Baltimore-Washington Parkway costing approximately $750,000. The need for this interchange is largely the result of the serious crowding of the Greenbelt interchange for the Baltimore-Washington Parkway by the location of the Capital Beltway interchange requiring left-hand turns for traffic coming onto Glenn Dale Road from the south and for traffic entering the parkway from the west and headed north. Marginal acceleration and deceleration lanes, due to the close proximity of the interchanges, also contribute to the hazard in this area during the peak traffic periods.

Isolated Hazardous Test Facility (GSFC)

This facility will provide for conducting hazardous-type tests to study, develop, and evaluate equipment and techniques required to support present and future space operations. It will be located on a remote site off the Goddard Center proper, south of Beaver Dam Road. This facility will be used for electromagnetic exposure and tests of squibs, explosive bolts, cocked mechanical separation, and erection mechanisms. It will also be used for testing jet-type control systems used for orientation and stabilization of spacecraft, low thrust rockets used for orbit trimming, inflight course correction, and retrofiring maneuvers. The construction of the entire facility will provide a safe means for conducting investigations of damage resulting from radiation or other high-energy fields and will also provide a safe means for containment of blast and fragmentation damage caused by scheduled and unscheduled detonation of high energy materials.

Development Engineering Building (JPL)

This project proposes the construction of a building consisting of an office wing and a laboratory wing which will include a total of 96,000 square feet. The office wing will consist of 58,000 square feet including a division office complex, ten section chief offices, engineering offices, design and drafting rooms, and six conference rooms. The laboratory wing will consist of 38,000 square feet, including eleven technical laboratories, a machine shop, stock room storage area, and a high-bay developmental laboratory. It will be of rigid frame construction and will have two floors of laboratory space on either side of a high-bay area in the center. The high-bay area will have a hook height of approximately 35 feet to handle spacecraft, components, mockups, ground handling and test equipment, shrouds, and interface components associated with the spacecraft and launch vehicle. The laboratories provided will accommodate such activities as pyrotechnics, temperature control coatings, instrumentation, circuitry, electromechanics, cabling, potting, spectrophotometry, in addition to a semiclean room, a machine shop, a stock room, a storage area, and a minimum number of offices.

Completion of this facility will eliminate twelve trailers now occupied by Engineering Mechanics Division personnel as well as 29,000 square feet of office-laboratory leased space with a monthly savings of $13,000.

Addition to the Space Flight Operations Facility (JPL)

This project provides for an addition to the Space Flight Operations Facility, JPL, from which the space flight operations, associated with the unmanned lunar and planetary programs of the NASA, are conducted. The facility, with the addition, will be capable of servicing the space flight operations associated with the multiple missions concurrently planned by the NASA.

The addition to the facility will consist of approximately 7,200 square feet to the west side of each floor of the existing facility, adding a total of approximately 21,600 square feet. The additional area will be used to house new analog and digital data processing equipment, communication systems, and a spacecraft video processing facility. Operational space for the technical personnel required to conduct the space flight operations will also be provided.

The competing nature of the lunar and planetary projects with respect to lifetime, transit time, and objectives establish clearly the requirement to service more than one mission simultaneously. The basic Space Flight Operations Facility possesses the capability of serving not more than two missions simultaneously, and then only marginally.

A secondary requirement for this project is the requirement established primarily by the lunar projects to process spacecraft video data in real and nonreal time.

Utility Installations (JPL)

It is proposed that the following list of utility projects be accomplished in the FY 1964 Construction of Facilities Program:

(1) Rework of a service road on north side of Telecommunications Building to serve new buildings.
(2) Installation of a Bailey Bridge over the Arroyo Seco to allow two-way traffic.
(3) Rehabilitation of laboratory water system.
(4) Demolition of buildings to provide building sites and to remove outdated structures.
(5) Construct new parking areas to replace those lost to new building sites.

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(6) Installation of 36-inch storm drain in canyon at east end of Laboratory.
(7) Landscaping of regraded areas around new buildings and roads.
(8) Construction of pedestrian mall between buildings 179 and 170 from road B to road C.
(9) Increase the capacity of the sewer system.
(10) Erosion control.

MATERIAL SERVICES BUILDING (JPL)

This project provides for the construction of a four-story Materiel Services Facility of approximately 53,000 square feet which will house all the functions and activities of the Materiel Services Division except the convenience stockrooms which are strategically located in other Laboratory buildings for the support of the technical divisions.

The facility will be utilized by the following activities:

(1) Mail service
(2) Inventory control
(3) Central stores warehousing
(4) Stores
(5) Receiving/Shipping
(6) Receiving inspection
(7) Property accounting
(8) Division offices

This building, in addition to consolidating the various departments of Division 72, will release space formerly occupied in the Administrative Services Building to sections of the Procurement Division and Financial Management Division and the NASA-WOO Residency. Eight trailers will be eliminated as well as 3,100 square feet of leased office-laboratory space resulting in a savings of about $3,000 monthly.

UNMANNED SATELLITE OPERATIONS FACILITY (AMR)

This project will consist of the design and construction of an engineering and laboratory building 155 feet by 178 feet. The building will consist of an 8,900-square-foot high-bay area, 8,900 square feet of shop space, and a two-story wing of laboratory and engineer office space containing 18,000 square feet. The total gross floor area will be 37,380 square feet.

The facility will provide the necessary working space for the preflight preparation, system testing, and final assembly of unmanned satellites. The existing unmanned satellite preparation facilities at the Launch Operations Center do not provide enough space to meet the 1965 calendar year flight schedules. The inadequacy of the existing facilities is further emphasized by the concurrent requirements of Atlas-Agena and Centaur based flight programs, including earth orbiter, lunar soft landing, and Venus and Mars fly-by missions. Provisions must be made for the simultaneous preparation of as many as four satellites with the additional possible requirement of providing backup satellites. Longer preparation times, plus overlapping launching schedules for lunar and planetary missions, will create a requirement for additional preparation and checkout facilities.

16 Applications Program

MORTON J. STOLLER
Director, Office of Applications

Broadly, the Office of Applications has been charged with the responsibility for determining potential applications for the knowledge becoming available as a result of the efforts being expended in the space program, and for conducting research and development studies and flight programs directed towards the eventual establishment of operational satellite systems. In the fulfillment of these objectives the Office has been organized into several basic program areas. These are Meteorological Systems, Communications Systems, Industrial Applications, and Future Applications Satellites.

The Meteorological Systems Program is directed towards conducting research and development and associated flight programs aimed towards providing both equipment and information that will contribute towards the establishment and support, in conjunction with the U.S. Weather Bureau, of a National Operational Meteorological Satellite System. More generally, the efforts of the Office are directed towards developing flight systems that will provide a better understanding of atmospheric phenomena, their motions, and life history. These flight systems include satellite systems as well as sounding rocket techniques and their associated ground support equipment. Active satellite flight programs in the meteorological systems program include Tiros and Nimbus. Studies are currently underway to determine the feasibility of and problems associated with a synchronous altitude meteorological satellite.

The Communications Systems Program is devoted to conducting research and development and flight programs which are directed towards realizing the potential of the several feasible communications satellite systems, and towards contributing to the establishment of operational communications satellite systems. In this program, investigations are made into the low- or intermediate-altitude active repeater satellites such as Relay and Telstar, into the synchronous altitude active repeater satellites such as Syncom, and into the passive reflector satellites such as Echo.

The Industrial Applications program is concerned with the identification, cataloging, and dissemination of innovations deriving from NASA's space program, which will feed into civilian industrial activities and contribute to the nation's economic growth. NASA has enlisted the aid of several research institutes, universities, and industrial firms to assist in the determination of those innovations, and in keeping track of the transfer of these potential applications to the industrial environment and providing means for distributing information concerning these innovations to the users.

Finally, the Future Applications Satellites group has been set up to investigate new areas for uses of satellite systems, to study the requirements, and to determine the feasibility and potential of such applications. There is no approved flight program in this area. Currently under study are such possibilities as a civilian navigational satellite system, and a satellite system which could be used to collect data from remotely located sensing and telemetering platforms.

Our major efforts and the areas of perhaps greatest interest are Meteorology and Communications. Presentations of these two programs are given in detail in papers 17 and 18, respectively.

The NASA center, which has responsibility for the major portion of the effort in both Meteorology and Communications is the Goddard Space Flight Center in Greenbelt, Md. A smaller effort in both areas is also expended by the Langley Research Center in Hampton, Va.

Questions, information, and suggestions concerning any of the matters discussed in these presentations should be directed to the Director of the Office of Applications at NASA Headquarters in Washington, D.C.

17 Meteorological Systems

WILLIAM K. WIDGER, JR.
Chief, Operational Meteorological Satellites, Office of Applications

The objectives of the NASA Meteorological Systems Program may be summarized as follows:

(a) Development of satellite system equipment and techniques, and satellite launchings, toward an improved understanding of the atmosphere; and the development and continued improvement of an operational meteorological satellite system.

(b) Cooperation with the U.S. Weather Bureau in the establishment and support of a national operational meteorological satellite system.

(c) Development of meteorological sounding rocket techniques for both operational and research objectives.

The first project in support of these objectives has been the highly successful Tiros program with its record of six spacecraft usefully placed in orbit. The general configuration of Tiros is shown in figure 17–1. From these six Tiros have come over 200,000 cloud pictures (fig. 17–2) and great quantities of atmospheric radiation data. Both types of data have been widely applied to meteorological research. The cloud pictures are also being regularly used in operational weather analysis and forecasting, as depicted in the schematic cloud analysis in figure 17–3 showing the coverage on the day Tiros discovered hurricane Esther.

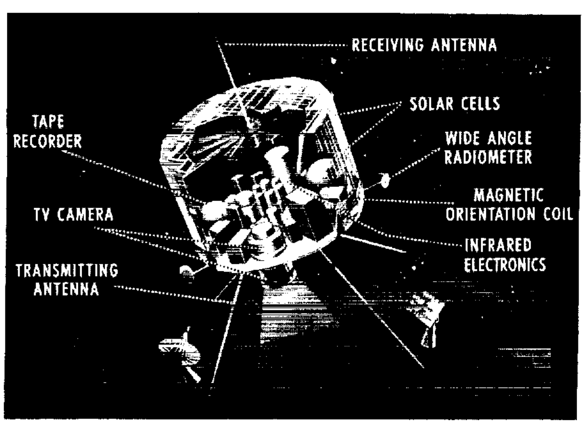


FIGURE 17–1.—Tiros spacecraft.

NASA has recently extended the Tiros program so that 5 more research and development launches are now planned for a total of 11. These R&D Tiros will be used to continue operational support of the weather services as well as for gathering new types of data or testing new sensors. The tentative plans for the R&D use of these Tiros are as follows:

(1) 15-micron radiometer to assist in development of Nimbus horizon scanner
(2) Automatic picture transmission for test purposes
(3) To provide TV and IR data in polar latitudes
(4) Will view disk of the earth from an eccentric 300- to 3,000-mile orbit
(5) May view disk of the earth from an apogee of 22,300 miles

The next Tiros, planned for the first quarter of 1963, will feature a 15-micron, carbon dioxide band, sensor in the five-channel scanning radiometer to obtain data on the horizon to aid control and stabilization system development. One of the others may serve for the first flight test of the Automatic Picture Transmission or APT system—the camera designed to provide direct readout of local cloud pictures to weather stations equipped with proper, relatively inexpensive receiving equipment. In addition, we are considering the feasibility of

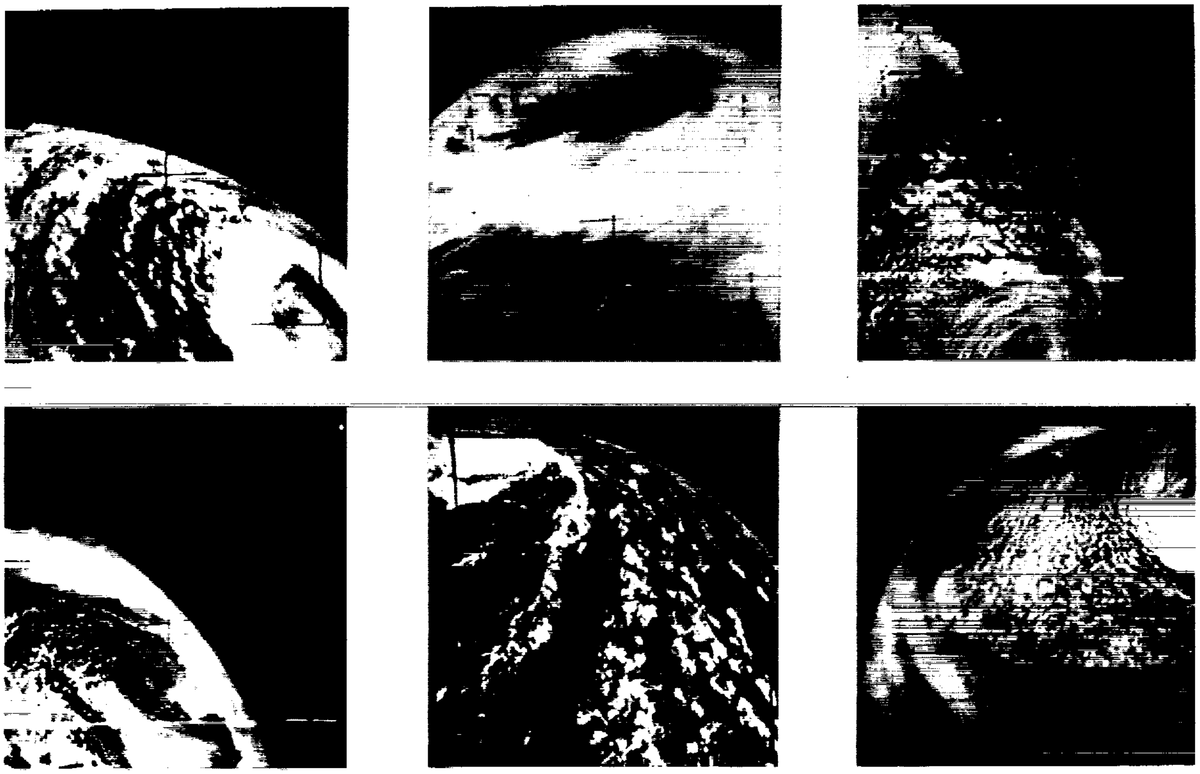


FIGURE 17-2.—Tiros cloud patterns.

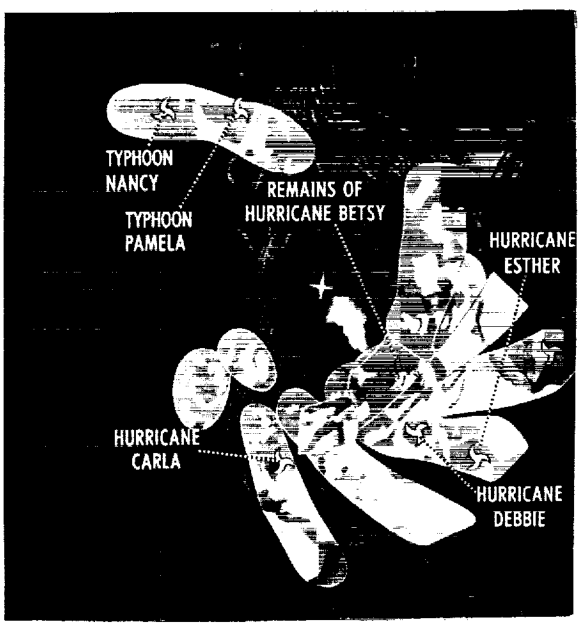


FIGURE 17-3.—Global cloud analysis, September 11, 1961.

a near polar orbit launch to provide data over essentially the entire earth, and eccentric orbits that would permit viewing the earth and its clouds from sufficient distance to permit seeing the entire disk at one time, thus simulating, at least in part, what would be seen by a synchronous meteorological satellite.

It is planned that all these Tiros, which will extend through and overlap the early Nimbus launches, will carry at least one camera for obtaining operational cloud picture data comparable to that obtained by previous Tiros.

In association with these additional Tiros launches, the Command and Data Acquisition station built at Fairbanks, Alaska, will be used to supplement the coverage of the present Wallops Island and Point Mugu stations. This will also serve to check out this station and its operational procedures prior to its use for Nimbus.

To increase the probability of maintaining adequate operational coverage prior to the availability of Nimbus, the U.S. Weather Bureau is funding for two additional Tiros which will carry only TV cameras and will be interspersed with the NASA R&D launches. With these, it is obvious that there are now more Tiros scheduled for future launch than have yet been orbited. But, more significantly, Tiros still has a significant R&D future, as the nature of the experiments planned makes obvious.

Next in order is Nimbus, a logical successor to Tiros and the primary spacecraft planned for the National Operational Meteorological Satellite System. Nimbus is shown in figure 17-4. Although a detailed description is unnecessary, it does seem desirable to emphasize that this spacecraft will be earth stabilized, and in a quasi-polar orbit, to provide complete global coverage. Furthermore, the relative independence of the controls, power, and sensory systems and the modular structure of the Nimbus sensory ring will simplify improvements or additions to later versions. Four NASA R&D Nimbus are specifically scheduled for the next few years, with four to five U.S. Weather Bureau funded operational counterparts to be interspersed to increase the probability of essentially continuous operational coverage. The first Nimbus is scheduled for launch in late 1963. It and the second (scheduled for the second quarter, calendar year 1964) will serve as the initial system test vehicles. The third and fourth R&D Nimbus, scheduled for launch in calendar years 1965 and 1966, will be for further development, especially with regard to the incorporation of sensory system redundancy. Nimbus has been designed with two objectives in mind:

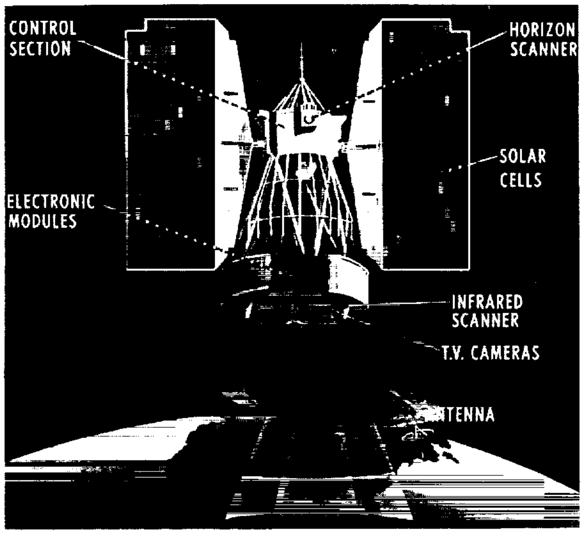


FIGURE 17-4.—Nimbus meteorological satellite.

(1) As a modular testbed to provide a flexible capability for future R&D, including both sensors and basic satellite systems.

(2) As the basis of the National Operational Meteorological Satellite System, as pointed out previously.

In Meteorological Systems there is also concern with the development of sounding rockets systems for exploration and measurement of the atmosphere in the region above 20 miles and below about 150 miles, accessible to neither satellites nor balloon borne instruments. This region serves as an important link between the variations in the solar radiation input and their effect on the lower regions in terms of air motion and the surface weather.

Sounding rockets as applied to altitudes of 20 to 40 miles, although they are for the most part still experimental, have revealed the potential of a network of sounding stations to systematic study of this atmospheric region. We are, consequently, interested in developing an economically practical meteorological rocket sounding system involving all components (motor, sensors, data acquisition, and data reduction).

The development and cost requirements for the system are rather stringent. The motor must be reliable. It must be capable of launch at a specified time under a variety of adverse weather conditions and its flight path must be reliably predictable to insure a small impact area. There is also a flight safety aspect which may be achieved by some form of frangibility or self-destruction which will permit safe operation at least over sparsely inhabited areas. The wind sensor should accurately respond to the smaller scale vertical variations of the wind. The temperature, density, and pressure sensors should provide accurate and as direct as possible measurements of ambient atmospheric conditions, with minimum reaction to outside influences such as solar radiation, radio frequencies, and so forth.

To permit use in a network, the data acquisition component should be an economic, self-sufficient unit independent of the expensive present range support equipment now required. The data reduction components of the system should permit rapid conversion of the telemetry records into the necessary meteorological units, allowing quick operational utilization, immediate dissemination of the data for analysis and application by various agencies, and systematic study of this atmospheric region.

Some of the small rocket sounding techniques which are presently used at various ranges are

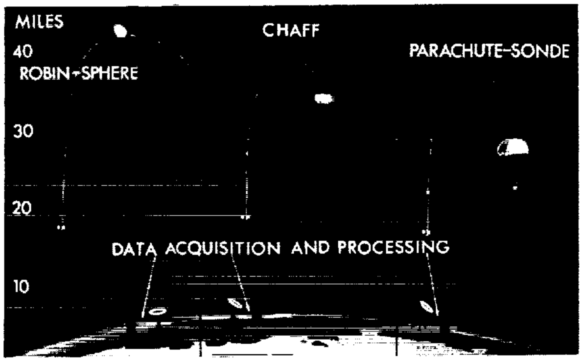


FIGURE 17-5.—Meteorological small sounding rocket.

shown in figure 17-5. In the first method the sphere's downward trajectory is tracked by radar and, from this track, the meteorologist can determine wind and density. Another technique uses a chaff payload consisting of a million or more small pieces of radar reflecting material. These, after ejection from the rocket at apogee, form a cloud of small needles which is tracked by radar as it descends to provide a measurement of the wind. The third technique employs a parachute and a temperature sensing instrument. As it descends, the measurement is transmitted continuously to the ground and the track of the parachute provides the wind measurement. None of the present techniques have as yet adequately fulfilled existing technical or economic requirements.

The larger meteorological sounding rockets methods are shown in figure 17-6. These techniques extend our knowledge of the upper atmosphere to altitudes above 100 kilometers.

In the first technique shown, a series of grenades are ejected and exploded, at intervals,

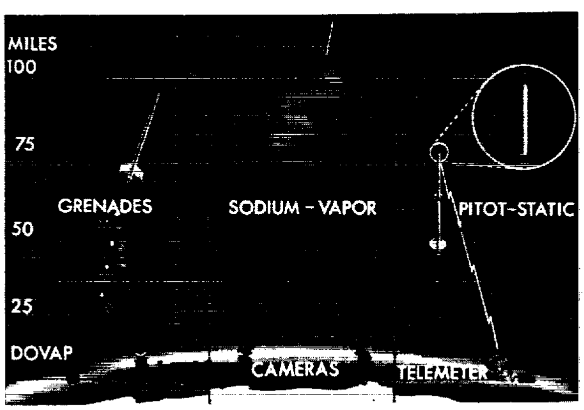


FIGURE 17-6.—Meteorological large sounding rocket experiments.

along the trajectory of the rocket. The location of the grenade at the time of explosion is determined by radar, or optically, and the time of arrival of the sound at the ground is accurately measured over an array of microphones. From these, wind and temperature are determined as a function of altitude. The next method releases a sodium vapor trail along the upper portion of the rocket's trajectory. Time-lapse photographs of the trail's deformation provide data for the compilation of wind velocity. The pitot tube technique provides onboard measurements of pressures (stagnation and static pressures) which are used to compute atmospheric density and wind.

Since these experiments are more costly than the small meteorological rocket soundings and require more range support and ground equipment, the planned number of launches must be less and the experiments judiciously distributed throughout the seasons of the year and at several locations. This will provide data for research on the effect of latitude upon the structure of the atmosphere in addition to the seasonal variation.

In this large meteorological sounding rocket effort, the Meteorological Systems Office works closely with the Office of Space Sciences since many of the experiments provide atmospheric measurements required by research and application in both meteorology and aeronomy. Also, where possible, these three experiments will be coordinated and include the launching of smaller meteorological rockets so as to provide more complete data on the atmospheric structure and estimates of the size of the atmospheric systems.

Efforts in this area will be toward improving the techniques and sensors and developing more economical systems of observations. This should permit an expansion of the temporal and spatial measurements of the upper atmosphere and extend knowledge of the dynamics of the atmosphere.

In-house preliminary design studies with regard to a possible synchronous meteorological satellite (fig. 17-7) have been underway for some time, and a contract for more detailed studies of the problems associated with such a spacecraft has recently been awarded. This study will indicate what significant further development of present capabilities is required. It should be emphasized that the synchronous meteorological satellite is not an approved flight

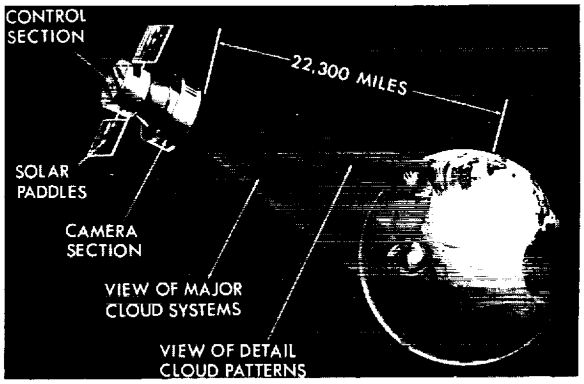


FIGURE 17-7.—Synchronous meteorological satellite.

program—only the study phase, through the recently awarded contract, has been approved.

Future opportunities for full development of basically new and different spacecraft will be limited. Rather, the most frequent opportunity for contractual participation will be:

(1) First and most widespread, in the field of Supporting Research and Technology (SRT) which will be the door to new technical achievements on which new spacecraft subsystems will be based. On a phased basis, with due regard for requirements and technical capabilities, the Aeronomy and Meteorology Division of Goddard Space Flight Center expects, over the next few years, to undertake programs in such areas as:

(a) Image orthicon cameras to observe clouds at night.

(b) Electrostatic tape cameras for higher resolution cloud pictures and more efficient storage prior to data readout.

(c) Improved infrared or other atmospheric radiation sensors, particularly spectrometers.

(d) Sensors operating in other parts of the electromagnetic spectrum, such as sferics, passive microwave, and possibly radar.

(e) Improved controls, power, recording, and command subsystems.

(2) The development, fabrication, and production of new or improved subsystems to be incorporated into later spacecraft. In general, these will be based on the results of previous SRT.

(3) Occasionally, the integration of new subsystems into modifications of existing basic spacecraft to produce advanced meteorological satellites.

Under the SRT portion of our program, we have many general requirements to be satisfied. First of all, for all subsystems—sensory and otherwise—we have the usual spacecraft improvement requirements. These include greater reliability and lifetimes, reduced space and weight, reduced power requirements, and greater efficiency and accuracy. Subsystems of concern include power, controls and stabilization, command, storage, transmitters, receivers, engineering telemetry, and so forth. For the sensory subsystems, improved resolution, contrast, sensitivity, and accuracy are also obvious goals. In all cases, improvements to be useful must be significant in magnitude. Those contemplating only a few tens of percent usually end up with a net improvement too small to justify the resources expended. These are general requirements applicable to many flight programs and are the primary responsibility of the Office of Advanced Research and Technology.

Second, new or improved sensory concepts are needed for attaining the meteorological measurements stated in existing requirements. These requirements include.

(1) Clouds
  (a) Cover (good present capability)
  (b) Patterns (good present capability)
  (c) Altitudes (partial present or foreseeable capability)
  (d) Night as well as day (partial present or foreseeable capability)
(2) Atmospheric heat and radiation balance parameters (good present capability)
(3) Temperature
  (a) Surface (good present capability)
  (b) Free atmosphere (partial present or foreseeable capability)
(4) Composition
  (a) Moisture (partial present or foreseeable capability)
  (b) Ozone
  (c) Other
(5) Winds
(6) Pressure
(7) Density
(8) Precipitation areas
(9) Sea surface conditions (partial present or foreseeable capability)
(10) Index of refraction
(11) Altitudes of significant layers, such as the tropopause
(12) Visibility and other atmospheric optical properties

It is obvious that while we are making excellent observations of a few of these required parameters and doing moderately well (presently or prospectively) on several others, many measurements are being made inadequately or not at all. In particular, we lack even reasonable concepts for measuring those dynamic parameters (pressure, winds, density, and accurate temperatures) on which most existing weather analysis and forecasting techniques depend.

In order to meet these requirements ultimately, there must be, over the next few years,

(a) Improved, more precise or sensitive measurements in the visible or infrared spectrum, and the sensory systems to make them

(b) Use of the ultraviolet spectrum where applicable

(c) New regions of the electromagnetic spectrum applicable to measurements of meteorological significance, such as passive microwaves, sferics, possibly radar

(d) New concepts of meteorological measurements or inference—some of which may yet remain to be even suggested

To this same end, we are also working closely with the NASA group concerned with Future Applications Satellites; this group is studying the feasibility of data collection and position location using satellites (fig. 17–8).

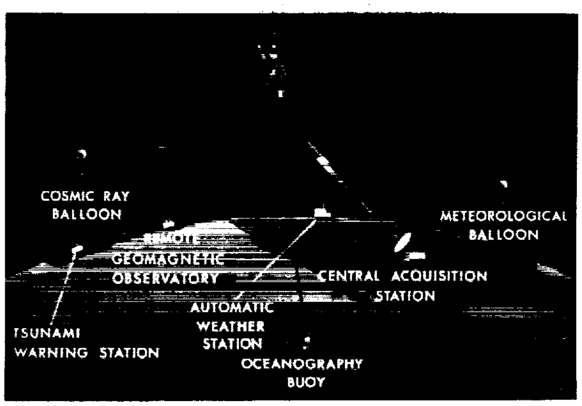


FIGURE 17–8.—Data collection by satellite.

As part of a broader capability, such a system could acquire meteorological data telemetered from remote automatic weather stations, oceanographic buoys, constant level balloons, and so forth, while also, where applicable, it could locate the geographic positions of such platforms. A contract to survey the requirements for such a satellite data collection capability is about to be negotiated; it is anticipated that a competitive Request for Proposals for a detailed feasibility study and initial engineering designs will be issued within the next several months. Present thinking in this area suggests that NASA will confine its interests to the satellite portion of such a system and, to insure system integrity, to prototypes of transponders compatible with the satellite subsystem. The desired observing platforms, sensors, and transducers would be the responsibility of those desiring to obtain and utilize the data.

Another area under the SRT program with significant requirements is that of improved data handling, storage, reduction, and initial presentation to the using meteorologists. On board the satellite we are concerned with:

(1) Improved storage or recording systems with

(a) Greater efficiency

(b) Greater flexibility, as for multiple, nondestructive readout

(2) Partial processing—simple systems to remove redundant or nonsignificant data while preserving all significant meteorological information. The objective would be to compress the data telemetered with consequent savings of bandwidth, time and/or power, and so forth.

Similarly, on the ground at the CDA station we would like to be able to reduce redundant or nonsignificant information further to conserve the bandwidths required for ground-to-ground transmission (probably the greatest presently foreseeable bottleneck in overall meteorological satellite systems) and to aid the meteorologist who is now faced with quantities of data which certainly stretch and probably exceed his capabilities for fully effective use.

As one possible approach to exploring and testing initially new or improved meteorological satellite concepts and techniques, we are considering the use of simple experiments that might be "piggy-backed" on a fail-safe noninterference basis on some of the remaining Tiros and perhaps later on the third or subsequent Nimbus. Ideally, these would share some of the capabilities of existing subsystems; for example, on a time-sharing basis or during periods when natural conditions (such as insufficient illumination) prevent employment of a system toward its primary objective.

In summary and conclusion, the NASA programs in Meteorological Systems include:

(1) The current flight programs: Tiros, Nimbus, and meteorological sounding rockets.

(2) Studies toward possible future efforts

(3) Supporting Research and Technology, which we consider the door to the future. From our viewpoint, this area is the one that will develop the technical advances necessary to the continuing fulfillment of our responsibilities. For industry, it is the gateway to the demonstrated experience required of potential flight hardware contractors. Although individually the tasks in SRT may be of relatively small size, the total the work required and the resources available are substantial.

18 Communications Systems

A. M. GREG ANDRUS

Acting Chief, Communications Satellite Technology, Communications Systems, Office of Applications

The following short excerpt is from the President's message to Congress in February 1962, when the new Communications Satellite legislation was proposed:

> Among the policy objectives . . . have been the assurance of global coverage; cooperation with other countries; expeditious development of an operational system; the provision of service to economically less-developed countries as well as industrialized countries; efficient and economical use of the frequency spectrum; non-discriminatory access to the system by authorized users. . . .

Consistent with these policy objectives, the objectives of NASA's Communications Satellite program are (1) to insure the full development and realization of communications satellite potentials through continued research, development, and flight test, and (2) to assist in the early establishment of operational communications satellite systems.

To achieve these objectives involves, broadly, investigation and exploitation of three basic techniques which are applicable to operational communications satellite systems. These are:

(1) Active satellites in low and intermediate orbits

(2) Active satellites in 24-hour synchronous orbits

(3) Passive reflector satellites in low orbits

Each of these techniques has advantages and disadvantages, and data are not yet available for final comparative evaluation.

This presentation will concentrate on future prospects; however, first a brief review of what has been done so far is given.

The spectacular initial success of Telstar, launched in July 1962 after successful experiments with DOD's Courier and Score, may have created an impression that a communications satellite system is already developed—at least in terms of a low-altitude active system—and all that is needed to make it operational are additional launches. Telstar experiments have provided a wealth of knowledge upon which design of operational communications satellites can be based, but there are still many problems to be solved before a civilian system can be made operational. The temporary failure of Telstar in November, and our difficulties with the Relay satellite launched December 13, 1962, serve to emphasize this point. Furthermore, Telstar and Relay represent only one of the three basic types.

We have no flight experience whatever with the class of satellite which holds great promise for future systems—the 24-hour synchronous orbit satellite. Experience with passive reflector satellites has been limited to that obtained with Echo I, the 100-foot sphere launched over 2 years ago.

Exploratory studies on an advanced intermediate-altitude active repeater satellite have been made and we are still in the process of identifying the various elements of research and advanced technical development which must be completed prior to establishing a flight program. Hardware development and flight plans do not exist. This is not because the intermediate-altitude type is obsolescent, but because we want first to gain more experience and knowledge via Telstar and Relay; also, much of the work which needs to be done to improve the technology of active repeater satellites is in the

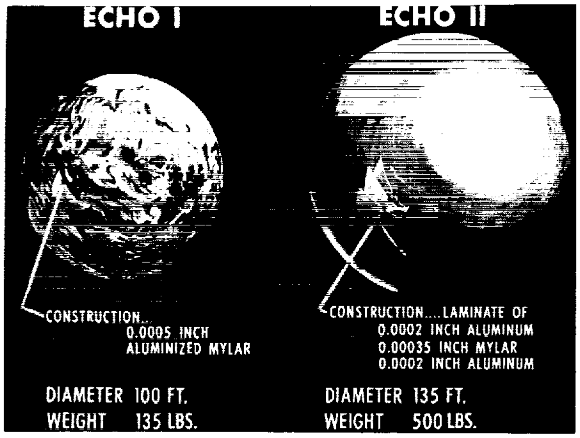


FIGURE 18–1.—Passive reflector satellites, Echo I and Echo II.

realm of studies and subsystem design which do not necessitate actual flight testing in early stages.

We expect to gain from Syncom a great deal of valuable information on the techniques of stabilizing and communicating with a satellite in a synchronous orbit. In 1964 and beyond, plans are to design and flight-test a new and better version of a synchronous satellite, which will have the capability of handling television bandwidths and will orbit in a 24-hour equatorial plane.

In the passive reflector area, there will be an orbital flight test of a 135-foot sphere, Echo II later in 1963 (fig. 18–1). In contrast to Echo I, it will have a different, heavier aluminum-mylar laminate material, and a different pressure inflation process may be employed to control the rate and extent of inflation more accurately.

No flight programs for passive reflector satellites are now scheduled beyond Echo II. Instead, our efforts will be directed toward development, test, and evaluation of the characteristics of new materials for erectable passive structures, both spherical and nonspherical; toward development and test of structures having nonisotropic reflection characteristics, such as spherical segments; and toward methods for erecting and for controlling the attitude of these structures.

Why continue with passive satellites, when they require ground installations larger and more complex than those required for active repeater satellites? Two of the reasons are: the passive reflector satellite is one relatively easy solution to the multiple access problem, which will be discussed subsequently, and its reliability is inherently good because it has no active elements.

The experimental flight programs have demonstrated the technical feasibility of employing satellites for intercontinental communications. However, they do not in themselves demonstrate or prove the technical and economic feasibility of a commercial satellite communications system. Many areas of technology must be explored and improved before operational systems become a practical reality. To this end, we will carry out an extensive program of supporting research and advanced technical development. In this area the resources, imagination, and talents of private industry can be applied to best advantage.

The general objectives of this supporting research and development program are to provide the foundation of new systems having capabilities as follows:

(1) Intermediate altitude active repeater satellites with increased communications capability, multiple access, passive or semipassive control system for orienting the satellite toward the earth, and powered by solar cell-battery combinations or by nuclear isotpe power supplies.

(2) Stationary, fully stabilized, high-gain satellites, with high communications gain and a long orbital lifetime, station-keeping and attitude control provided by electrical thrusters, power to be provided by solar or nuclear power supplies.

The characteristics and capabilities of present active systems are compared with the anticipated characteristics and capabilities of the follow-on systems in table 18–I.

If passive reflector satellites are to be competitive with active systems, structures are needed having substantially greater radio cross section, less weight per unit area, and less susceptibility to orbital perturbations.

To realize these objectives, we plan to pursue programs in these specific areas:

Antenna Technology. Higher gain communications antennas aboard the spacecraft would enhance the effectiveness of the limited on-board RF power capabilities; however higher gain, narrower beam antennas require that the spacecraft be stabilized more precisely, and stabilization capabilities will set the limits for antenna gain and directivity. To get

TABLE 18–I.—*Active Communication Satellites—Systems Improvement*

Systems	Launch vehicle	Weight, lb	Orbit: Statute miles	Orbit: Shape	Channel	Stabilization	Percent of time available	Number of stations
Low altitude:								
Relay	Delta	150	700 to 3,000	Elliptical	1 television	Spin stabilized	10	2
Advanced satellite	Atlas-Agena B	600	Up to 12,000	Circular	4 television	Earth oriented	25	Many
Synchronous:								
Syncom	Delta	55	22,300	Inclined	1 telephone	----------	75	2
Advanced satellite	Atlas-Agena B	500	22,300	Equatorial	4 television	----------	100	Many

around this limitation, self-tracking techniques will be explored hand-in-hand with the investigation of techniques for higher gain. This year we plan to place a study contract to determine the state of the art in all-electric beam shaping and steering techniques, tracking, and so forth. Future work will depend on the outcome of this study.

Transmitter and Receiver Technology. Power output of the spacecraft transmitter is the major information-limiting factor in today's experimental systems. Even moderate transmitter improvements are beneficial, as the spacecraft-to-ground link is the critical one in terms of signal-to-noise ratio, so long as onboard power is severely limited. As one approach to transmitter improvement, we plan to explore direct RF-to-RF conversion, without intermediate frequency amplification. This may increase power efficiency; any attendant simplification will improve reliability. For spacecraft receivers, one obvious improvement is to reduce the noise figure below the presently typical figure of 12 to 14 decibels to enable the use of less costly and less complex ground equipment, thereby enhancing the application of satellite communications to "thin routes." Another desirable improvement in ground receivers is to improve the bandwidth capabilities of phaselock systems beyond the 3 megacycles achieved to date.

Modulation Methods. Present active satellites can be used by only one pair of stations at a time. It is manifest that future satellites must be available to a number of users concurrently. (See fig. 18–2.) Although this might be accomplished by RF selectivity, a more promising approach is via modulation and multiplexing schemes on a single RF channel. Our modulation-multiplexing studies will be conducted in two distinct phases. The earlier phase, applicable to the Advanced Synchronous program, will be to develop a single sideband exciter—transmitter capable of compensating for Doppler and for spacecraft receiver oscillator drift, having power level control proportional to channel utilization, and permitting control of the number and spectral position of voice channels according to traffic demand and usage of the RF channel by other stations. Another phase will be a broader study of modulation techniques applicable to multiple access to include synchronous and asynchronous pulse systems.

FIGURE 18–2.—Multiple access communications satellite.

Passive Techniques for Stabilization. In higher orbits the gains available by the use of directional rather than isotropic antenna systems offers a way to obtain a large increase in system capability at no increase in on-board power; however, the complexity, cost, and weight of the stabilization equipment required largely or completely negate this improvement (except for the 24-hour orbit). Passive stabilization if it can be achieved without undue complication appears to be a way to attain a large increase. NASA has sponsored work in this area and will continue to monitor progress, conduct theoretical studies, and, when the time appears appropriate, conduct hardware development.

Passive Structures With Improved Scatter Characteristics. We want to increase the radio cross section of passive satellites by an order of magnitude *without* a commensurate increase in weight and without a commensurate increase in the area acted on by the solar pressure. Two approaches are expected to be pursued. One involves use of metallic mesh, with or without an interconnecting plastic web. That is, if we are limited to pressurizing as a method of erecting the satellite, a vapor-tight sphere is necessary initially, but some method should be found for decomposing the plastic, after erection, to reduce solar pressure effects. Another approach involves investigation of structures having nonisotropic reflection characteristics, and of an attendant technique for stabilizing them to keep the reflective surface positioned properly. Corollary work will be done on packaging and erecting or inflating these structures in space, and on practical methods for measuring, on the ground, the gain, frequency response, and directional characteristics of the materials and structures.

System Comparison and Optimization Studies. The principal and earliest objective in this area will be to determine, within each of the three basic systems types, the trade-offs which can be made between the satellite and ground station, technically and economically, to balance reliability and cost per unit of communication capability per year. Such a study has been carried out for passive systems. Active systems will undergo a similar analysis. Another area for study is the subjective reaction of the customer to time delays inherent in synchronous altitude systems, and to less-than-standard TV signal-to-noise performance.

Frequency Utilization. Only time will tell whether the planned sharing of fixed "common carrier" bands between ground point-to-point services and satellite services will result in acceptably low interference levels to both parties. Regardless of the degree of success, however, it seems inevitable that frequencies above 10 gigacycles will be used eventually, for satellite-to-satellite communications or for ground-to-satellite circuits. Hence, we plan further studies of propagation aspects above 10 gigacycles, and studies of equipment technology to determine the feasibility of both ground and spacecraft configurations.

Reliability. First Courier, then Telstar and Relay, served notice that we are still far below the level of reliability necessary for operational systems. Hence, we must continue and intensify our tests and analyses of component, subsystem, and system reliability under carefully simulated environmental conditions. Individual components must have extremely long life; subsystems must be as simple and straightforward as possible consistent with the function to be performed; and systems must be analyzed and designed to minimize the consequences of a failure when one does occur. Reliability analyses must be matched by failure analyses, and the system designed to compartment failures in the same sense that a ship is compartmented to minimize the likelihood of sinking.

These goals are not easily reached, and the program will undoubtedly have its carryovers beyond FY 1964 and 1965.

The technical facilities offered by communications satellites certainly excite the imagination. The need for the capability afforded by satellites is urgent, and there is general agreement among all concerned to proceed with their development as rapidly as possible. This attitude was best expressed by President Kennedy in a public statement a few months ago in which he also acknowledged another and perhaps even greater promise of communications satellites. He said, "There is no more important field at the present time than communications, and we must grasp the advantages presented to us by the communications satellite to use this medium wisely and effectively to insure greater understanding among the peoples of the world."

19 Introduction to the Advanced Research and Technology Programs

RAYMOND L. BISPLINGHOFF

Director, Office of Advanced Research and Technology

Every major Government office serves some group of people who need the services provided. The product of our advanced research and technology program is new, tested, and advanced engineering design information. The primary users of this product are engineers of the aerospace industry.

Key technical areas of the Office of Advanced Research and Technology will be discussed in subsequent papers. The six principal fields of responsibility of the Office of Advanced Research and Technology are shown in figure 19–1.

The mission of this office is the timely creation of advanced technology to meet future space needs. For this purpose we guide and support three related areas of activity. These are as follows:

(1) Basic research toward the understanding of natural laws underlying aeronautical and space technology

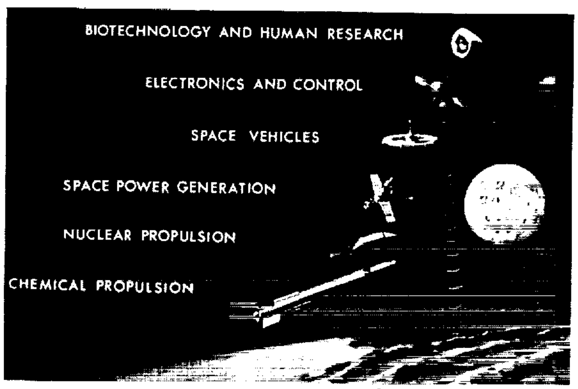


FIGURE 19–1.—Advanced research and technology for future activities in space.

(2) Engineering research for the development and detailing of engineering design principles

(3) Subsystems research, using experimental subsystems to produce tested "know-how" for the design of advanced operational systems.

The process of creating new space technology employs the resources of universities, research institutes, NASA research centers, and, on a large and growing scale, segments of industry. Each kind of institution makes important contributions to the first area, that is, to basic research. Our aim in basic research is to contribute modestly to the fund of scientific knowledge and to maintain the best possible contact with the scientific community.

Engineering research, that is, the creation of engineering design principles, is a focal point of effort in all these types of institutions. Industrial laboratories, university engineering schools, research institutes, and NASA centers are vigorously engaged in it. Our aim is the most efficient possible investment of both corporate and Government funds in this area. Discussions with industry on the direction of this work is a continuing and major activity through the NASA Research Advisory Committees and through many informal meetings. We are always happy to discuss, informally, specific ideas, and to indicate those that appear most interesting to us.

During the past decade, the increasing complexity and performance requirements of aerospace systems have led to serious problems. Crash developments using old technology have led to high costs, marginal performance, major retrofits, and short useful life of new systems.

This has led to the emergence of a new step in the R&D process—the third step referred to previously. It centers on the development of advanced, but purely experimental, major subsystems. Such devices may never fly an operational mission, but they can provide know-how in time for use in a whole family of very advanced operational systems.

An earlier difficulty, now somewhat ameliorated by the NASA policy embodied in our office, is the requirement for early funding of these advanced subsystems. In the past, Government agenices have found it difficult to provide such funding. Their efforts to develop urgently needed systems, using marginal technology, often preempted the available funds.

NASA, through the Office of Advanced Research and Technology, provides funding in these areas. Our aim is to develop a sound growth of this kind of activity. The recent growth in the scale, and the technical complexity of Federally sponsored research has caused a radical increase in the amount of such work done by industry. As a result, there is emerging a novel role for industry—one might even say, a new kind of industry. The product may not be physical goods, but information—useful, new scientific and technical information. This information is produced for profit in a competitive market. The Government is the buyer, with Federal funds. The product is commonly regarded as public property, and most of it is in the public domain.

At the same time, industrial research using corporate funds to generate proprietary information continues at a substantial level. Corporate-funded research, which could be termed seed research, plays a vital role because it often permits early exploration of ideas and their development to a point where Government funding can be obtained.

This industrial role has many novel characteristics. It requires new viewpoints and procedures. Our office, on the Government side, arose out of the same circumstances that are producing these industrial changes. They are pointed out here, because, at the senior management level, they will require continued study and discussion between Government and industry.

Consider the steering of such an advanced research and technology program. It must be diversified, covering almost the whole range of science and technology. Yet it must also be focused upon a clear purpose: To supply advanced technology suited and timed to meet future U.S. aeronautical and space needs. In our steering process, forecasted national requirements are derived from the NASA Long-Range Plan and other sources. These are compared with forecasts of our program achievements. The difference could be termed a program steering signal. Our office, with policy guidance from the Associate Administrator and discussions with centers and contractors, puts out revised program actions and achievement forecasts.

An understanding of this process should help industry to estimate the nature of NASA's research needs.

Our planning begins with a study of future aeronautical and space missions. For example, the principal bodies of the solar system which may be involved in space missions of the foreseeable future are listed in figure 19–2. Such celestial bodies are Earth, Moon, Mars, Venus, Jupiter, and Saturn.

Each mission involves some, or all, of the basic operations shown in figure 19–3.

Parametric studies are made to find the best technical approaches to these operations for each mission. We search particularly for techniques applicable to a wide range of missions. This process defines the nature of future advanced experimental subsystems, and of future flight programs. It also guides us in choice of patterns of engineering research projects flow-

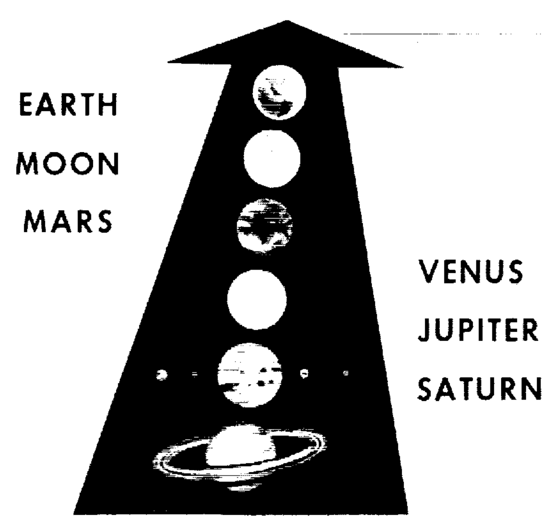


FIGURE 19–2.—Future space missions.

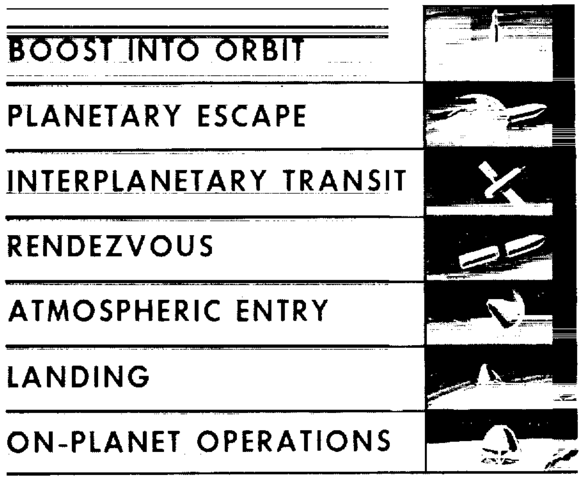


FIGURE 19–3.—Basic space operations.

ing toward readiness for future experimental subsystem design. A similar process guides our program in aeronautics where the program is aimed at the solution of all important problems of airborne transportation. These may range over the spectrum from hovering to hypersonic flight and from ground level to the fringes of space.

The broad research fields involved in space operations are the basis for the organization of our office. They are as shown in figure 19–4.

Fundamental scientific research is pulled together under a separate director, and supports the interests of all of the other directors.

The responsibilities of the Director of Aeronautics are also of a special character. Although his principal responsibilities are those of aeronautics research, under him are brought to-

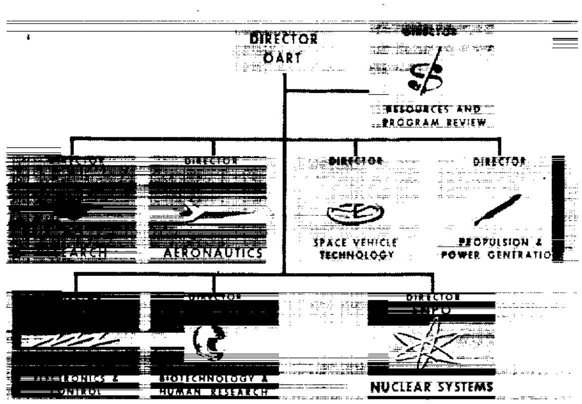


FIGURE 19–4.—Organization of Office of Advanced Research and Technology.

gether all of the NASA interests and functions which embrace the aeronautics field.

The Director of Space Vehicle Technology is responsible for research on structures, space environment, and aerothermodynamics. He also conducts systems studies related to future space missions, and provides a management service for all of the Office of Advanced Research and Technology space flight projects except those connected with the nuclear program.

The Director of Propulsion and Power Generation is responsible for liquid and solid chemical rockets, as well as chemical and solar power research.

The Director of Electronics and Control has the research fields indicated by his title as well as those of communications and guidance. He is also responsible for the technical aspects of the development of the proposed NASA electronics center.

Our newest major area is Biotechnology and Human Research. It encompasses research on the capabilities of man and the problems of integrating him into vehicle systems. This program is still in the formative stage, and will probably grow substantially over the next few years.

The Director of Nuclear Systems handles the NASA aspects of the national nuclear space power and propulsion program. The special features, and the technical interests, of that program will be discussed at length in a subsequent paper.

The Space Nuclear Propulsion Office is managed by Mr. Harold Finger, who is also the Director of Nuclear Systems. This office coordinates the NASA and AEC phases of the nuclear program.

The Director of Program Review and Resources Management has among his responsibilities the coordination of our research facilities program.

The NASA centers are our main instruments for research management. The bulk of our funding and technical guidance for industrial contracts is done through them. Each of the centers receives support for the research component of their program from our office. In general, each center is engaged in several major areas of our technical program.

The funding level for our work is shown in table 19–I. As shown, our total funding for FY 1963 is $464 million and we anticipate it to be some $571 million in fiscal year 1964.

TABLE 19-I.—*Estimated Budget (millions of dollars)*

	Fiscal year 1963	Fiscal year 1964
To industry	$340	$420
Nonindustrial	124	151
Total	464	571

About 75 percent of our budget goes to industry. We estimate the industry part at about $340 million in fiscal year 1963 and $420 million in 1964.

The approximate breakdown among various kinds of industry is shown in figure 19-5. Substantial sums go to industries not directly engaged in the production of research. It may be seen that the largest proportion, that is, $145 million in fiscal year 1963 and $224 million in fiscal year 1964, will go into direct support of R&D in industries which are carrying out advanced research and technology. Some $68 million in fiscal year 1963 and $74 million in 1964 will be spent on R&D equipment such as instruments and technical supplies. About $50 million in 1963 and $59 million in 1964 will be spent on the purchase of general supplies for our research centers. Finally, some $77 million in fiscal year 1963 and $63 million in fiscal year 1964 will be spent on the construction of research facilities.

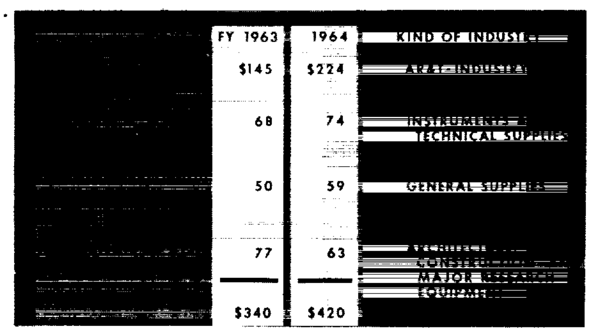


FIGURE 19-5.—Estimated budget—industry segment; OART program trends.

The segment representing the newly emerging kind of industry referred to previously, that is, the performance of Government-sponsored research for profit, is shown in figure 19-6 by the shaded bars. We believe that the growth of this segment will continue. Compare it with the relatively smaller growth of NASA center personnel.

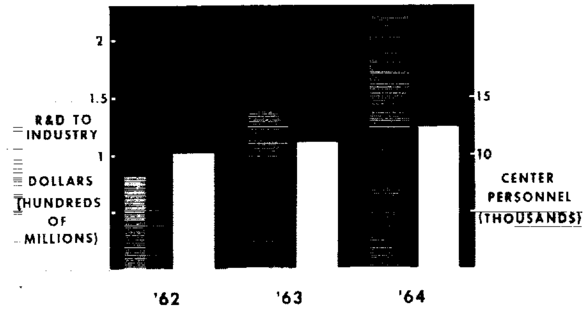


FIGURE 19-6.—OART program trends.

The number of contract dollars per center professional man has been growing rapidly, and will undoubtedly continue to grow. Hopefully, industry will provide the best possible people on its side of the "Government-Industry interface," and will consider the Government's interest as carefully as it does its own. If industry does this, the limited number of Government people will be able to handle their responsibilities to industry, and all will benefit.

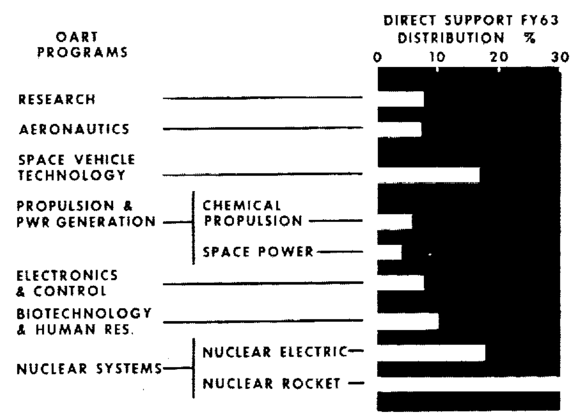


FIGURE 19-7.—Direct support of R&D by technical area, OART.

Figure 19-7 presents the distribution of "direct support" funds among our technical directors. About 90 percent of these funds go, either through the centers or directly from headquarters, into industrial contracts. It is evident that the largest items are in the nuclear systems programs, in which substantial contractual commitments and a number of advanced experimental subsystems already exist. Of the budget indicated for the Director of Space Vehicle Technology, about half is for support of the nonnuclear part of the OART space flight program. This program includes experiments sponsored by other directors. The centralized management furnished by the Director of Space Vehicle Technology improves coordination and economy.

20 Basic Research

HERMANN H. KURZWEG

Director of Research, Office of Advanced Research and Technology

The word "research" is used for a great variety of work within NASA's activity. Covering a wide spectrum, it reaches, on one side, far into the hardware, engineering, and technology and on the other side into the realm of the fundamentals of the physical, mathematical, and biological sciences.

Without exploring, understanding, and mathematically formulating the phenomena in these areas, progress in the building of vehicles, in astronautics, and in cosmology would be very slow indeed, if our present reservoir of knowledge is not continuously replenished. NASA has recognized that this kind of basic research must be integrated in the overall program and vigorously pursued.

Although this research is not directly connected, in general, with a vehicle under design, some of the newly obtained results are rapidly incorporated into designs, thus preventing costly technological errors in empirical approaches. Generally, however, the results are of benefit to research in advanced concepts for vehicle design.

A large part of our basic research is carried out in our own research centers. In this way a close contact with current NASA projects is possible, a contact which is necessary to stimulate the basic research trends towards the goals of the agency. It is mandatory, however, that NASA's scientific staff stay in close contact also with the corresponding groups in the other governmental, industrial, and university laboratories to obtain the most advanced knowledge in the field. A significant part of our basic research is carried out through a contract program with industrial laboratories. We depend very much on the participation of industry in the advancement of knowledge in all scientific disciplines, especially those discussed subsequently and those in which industry has already made substantial contributions.

Since space science and biological science are covered in other papers, a brief outline of our program in the physical and mathematical sciences, illustrated by a few examples, will be given in this paper. Basic research is carried out in the fields of fluid physics, electrophysics, materials, and applied mathematics.

Contrary to the thinking of some people there are still many serious problems connected with the motion and interaction of fluids and solid bodies. Stability, transition, flow separation, wake, and noise phenomena of a space vehicle during flight in the terrestrial and other planetary atmospheres have unknowns which must be explored before vehicles which are able to land and take off can be designed. Figure 20–1 shows the results of theoretical studies and experiments on an aerodynamic stability problem in carbon dioxide-air mixtures. As can be seen, this flared-body shape loses considerably its degree of stability in CO_2 enriched atmospheres. The white rings are the experimental results. It is interesting to note that the probable amounts of CO_2 in the Marsian or Venusian atmosphere have a pronounced effect on stability.

The high temperatures and associated heat, produced by the ever increasing speeds, continue to create severe difficulties with respect to heat transfer and body protection. A great deal of effort was spent on this problem. Figure 20–2 shows typical progress in the basic explora-

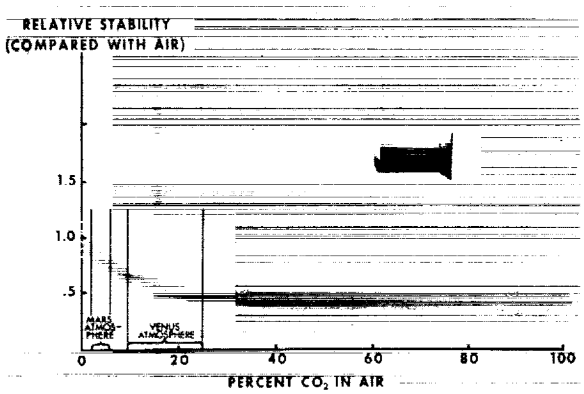


FIGURE 20–1.—Aerodynamic stability in carbon dioxide—air mixtures.

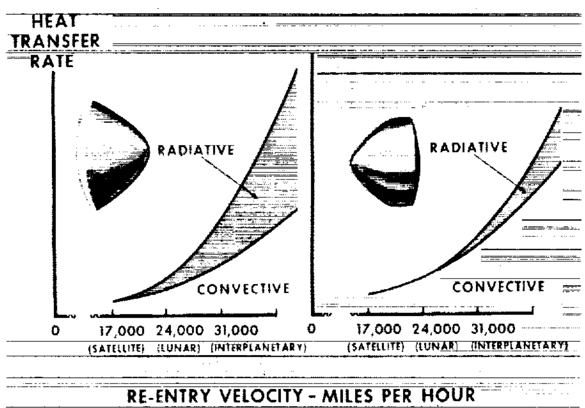


FIGURE 20–2.—Effect of nose shape on reentry heating.

tion of the effects of thermal radiation at speeds beyond those of Moon missions. According to this figure the blunt body shape on the left side—so far considered to be the final solution of the heat transfer problem—must be slenderized again—as indicated on the right side—in order to reduce air compression and thus keep the radiation component of the heat transfer small. The upper curve on both sides indicates the total heat rate; the area between the upper and lower curves indicates the amount of thermal radiation. Such a return to more slender shapes is interesting because it shows impressively the progress of thinking and advancement of knowledge in basic research. It is interesting and amusing that cyclic changes, back and forth, between blunt and slender bodies, are not new in the race for higher speeds at all times of history as figure 20–3 shows. Going through history, compact rocks were replaced by slender arrows; the concept of powder guns created cannonballs; the rocket age produced slender forms again which, ironically, finally got blunt noses. Now a new slenderizing process is in the making. It is also interesting to see how long it took to make such changes empirically and how rapidly these variations have been made by following scientific principles.

An example of our efforts in electrophysics is shown in figure 20–4. Lasers are a typical product of basic thinking in atomic physics. Here, our particular interest is not so much what we can do with them—another group takes care of that—but to explore the physical phenomena associated with the atomic and molecular structure of matter and to study the pertinent interactions of atoms and electrons. In this way, we hope to find better or new ways to stimulate radiation in new substances with frequencies in the wide open spectrum. Note the logarithmic frequency scale at the lower part of the figure which indicates the tremendous basic potential of the lasers for communications.

Basic work is going on in the field of superconductors which might become important in many space technology areas. Here the guiding thoughts are based on questions such as:

What makes a material superconducting?
What possibilities are conceivable for increasing the magnetic flux in a material in the superconducting state?
What are the areas where superconductors might find their way into applications?

The research program aims towards the answer of such questions.

Work on materials is quite active in NASA with a strong reliance on the work in the in-

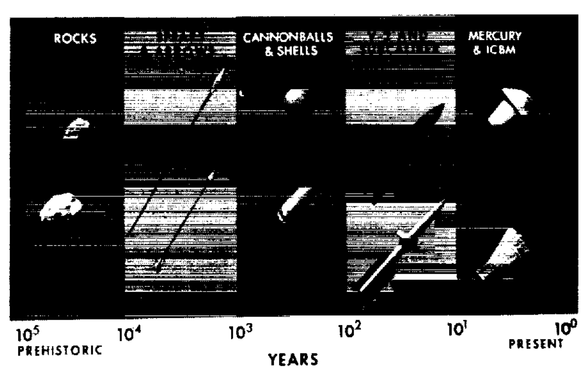


FIGURE 20–3.—Cyclic variations in projectile shapes, blunt and slender.

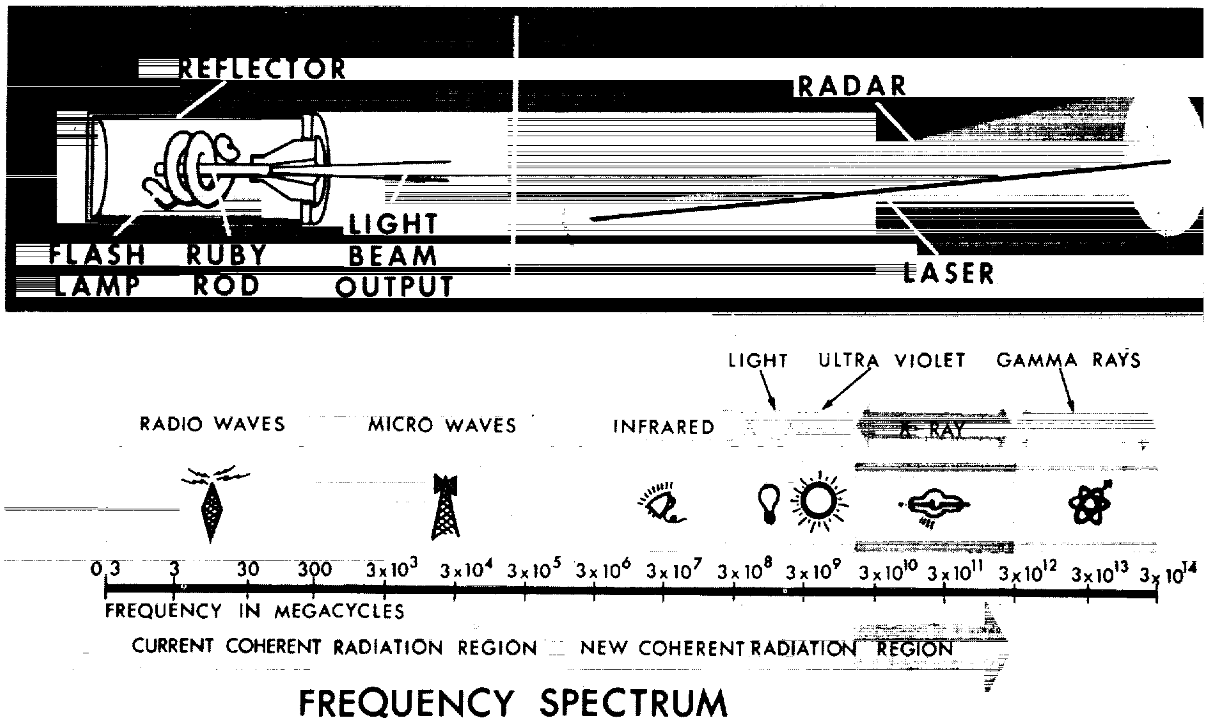


FIGURE 20-4.—The laser.

dustrial laboratories. This area of research is usually thought of as more applied in character because materials of all kinds are needed immediately in structures for vehicle designs which are presently on the board. Therefore, a great deal of our materials work is done in connection with special projects.

Figure 20-5, for example, shows the research on light structures made from metal foils. In the upper part of the figure three possible uses are indicated with suitable materials. The lower part shows some of the problem areas. The requirements for strong, high-temperature-resistant materials with a minimum weight are of a continuous nature and receive special attention by the Office of Research. There is, however, a great effort spent to explore the basic characteristics and behavior of pure elements, especially in the solid state, alloys, and chemical compounds. Without a basic understanding of the atomic and molecular structure, the forces between atoms, and the processes by which atoms move, changes of properties are hardly predictable. With pictures like figure 20-6, obtained with a field ion microscope, showing directly the position of atoms in a tungsten surface, new concepts of atomic relationships are bound to appear in the future which will allow variations of properties as needed for a special purpose. Interest in space age materials lies not only in the area of metals. Ceramics research and polymer chemistry play an important part in our materials program. Another example, lubricants to withstand high temperature and high vacuum, shows the need for special characteristics and shows that requirements become continuously more severe.

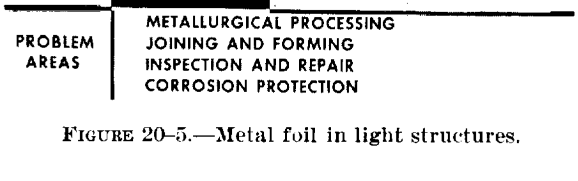


FIGURE 20-5.—Metal foil in light structures.

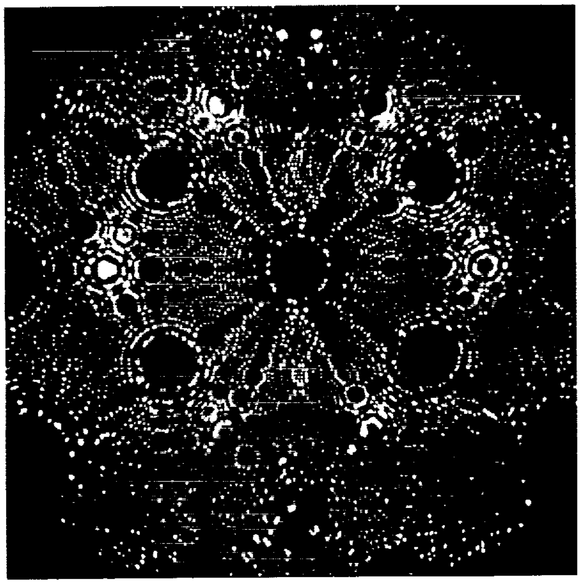


FIGURE 20-6.—Atomic configuration shown by field in emission microscopy.

Figure 20-7 shows the trend during the last 15 years and the expected goal for 1965. Lubricants of a liquid base are replaced by such materials as metal compounds and ceramics. The goal being in 1965 a temperature resistance of more than 2,000° F.

Briefly, mention may be made of our activity in applied mathematics within the basic research area. As has been pointed out previously, the mathematical formulation of the laws governing physical processes is a prerequisite for systematic and rapid progress in the technical world. It is therefore necessary to introduce mathematical methods and principles at an early stage in physical investigations. Many of the modern problems cannot be solved at all without mathematical approaches and especially without the use of high-speed computing machines. One the other hand, however, complex computers are not always needed to obtain information from analytical deductions which give our thinking a new direction. To maintain this mathematical ability in our research staff is the purpose of the special division of Applied Mathematics.

In summary, these few highlights may give an indication of our work and goals in the basic research area, and what role the industrial laboratories might play in the advancement of basic knowledge necessary to accomplish NASA's mission. It is, relatively speaking, a small part of NASA's total activity. In absolute figures, approximately 800 professional personnel in the research centers are actively engaged in this research, assisted by outside contracts utilizing about 40 percent of the basic research budget.

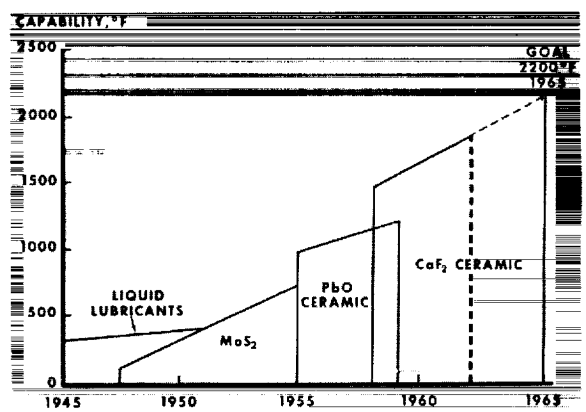


FIGURE 20-7.—High-temperature lubricants.

21 Aeronautical Research

CHARLES H. ZIMMERMAN
Director, Aeronautical Research,
Office of Advanced Research and Technology

Aeronautical research, broadly speaking, is aimed at solution of the problems of airborne transportation—hypersonic or hovering, military or civil, manned or unmanned from ground level to the fringes of space. The major portion of the NASA aeronautics activities are carried out through in-house research although about one-third of the aeronautics budget is categorized as Research and Development funds. About one-half of these R&D funds are programed for contract studies whereas the other half are for direct support of the in-house programs through the purchase of services, instruments, wind-tunnel models, special materials, and computer components or the rental of specialized equipment. A variety of missions and vehicle types are of interest and the research required involves a number of disciplines or specialized fields.

The three most challenging types of vehicles from the technical point of view will be discussed in this paper. These are the vertical or short take-off and landing vehicles, the supersonic transport, and the hypersonic cruise vehicle. Each of these potentially has an important place in our overall ability to transport people and things from place to place on the earth, economically and safely.

In figure 21–1 some of the vehicles currently being considered in these three categories are illustrated. A helicopter and tilt-wing airplane are examples of the relatively slow, short-range aircraft needed for local transportation. Above these are supersonic transport concepts which would be capable of crossing the Atlantic Ocean, for instance, in less than 2 hours. In the upper left is a hypersonic aircraft which, if developed, would be useful on longer flights such as from this country to Australia. Reference to our current propeller-driven and jet aircraft has been deliberately omitted. We will maintain a continuing research program for these types of aircraft, but our primary emphasis is being placed elsewhere.

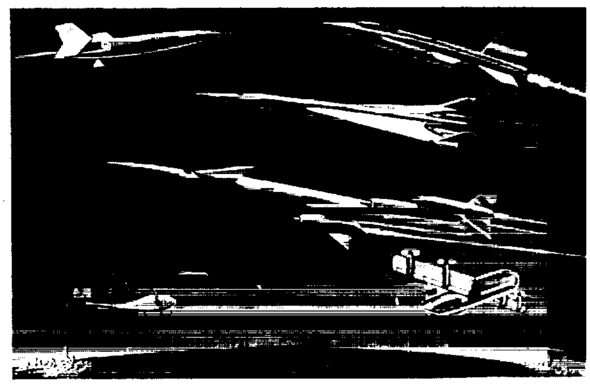


FIGURE 21–1.—Aircraft types now being studied by the NASA.

V/STOL AIRCRAFT

In recent years, the vertical or short take-off and landing (V/STOL) aircraft has been suggested as the best—and in some cases, the only—means of satisfying a variety of transportation needs, both civil and military. Numerous aircraft concepts have been proposed to best attain the lift required for vertical take-off. NASA flight and wind-tunnel studies of many of these basic configurations have indicated several concepts that appear feasible for given missions.

Figure 21–2 indicates some of the military uses proposed for V/STOL vehicles in a limited war. Configurations incorporating the tilt-duct or tilt-wing principle appear particularly promising for the medium-range subsonic

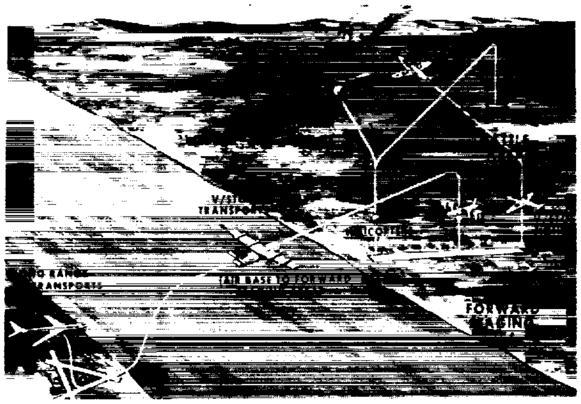


FIGURE 21-2.—Military V/STOL aircraft.

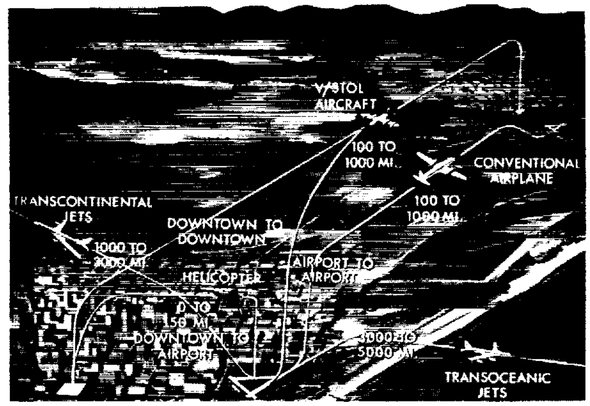


FIGURE 21-3.—Commercial uses of V/STOL aircraft.

transport carrying troops and supplies to forward staging areas having relatively unprepared landing fields unable to handle conventional transports. For higher speed fighter aircraft operating in this area, a deflected-jet or lift-engine type may be the most suitable. For missions requiring long periods of hovering, or operation in more inaccessable locations, and for rescue, the helicopter will probably continue to be the most practical aircraft. It might also be pointed out that, in the aftermath of a more serious, nuclear war, V/STOL aircraft might be the only type of transportation possible in many areas.

Figure 21-3 indicates the potentially greater use of V/STOL aircraft in civil application. The use of helicopters for downtown-to-airport, or "local" transportation (that is, for distances up to 50 miles) has been shown to be practical and such use is expected to increase in the future. Practical application of some other type of V/STOL transport—probably using the tilt-wing, tilt-duct, or deflected-slipstream concept—is foreseen for longer subsonic civil flight requirements. These "missions" include "feeder-line" operation (50 to 150 miles), transporting passengers with minimum delay from regular airports to those few terminals servicing the new supersonic-transport aircraft, for example, and short-haul (150 to 350 miles) and perhaps medium-range (350 to 800 miles) flights from relatively small "close-in" airports, decreasing city-to-city transportation time. Such aircraft will permit the steep climb outs and approaches required to avoid building obstruction and noise nuisance in such congested locations. It is believed these types of operation are possible if careful attention is given to proper use of available airspace and runways.

In the immediate future our wind-tunnel research effort will be concentrated primarily on studies of problems—such as wing stall, improved stability and control, and alleviation of adverse interference effects—of subsonic V/STOL types (illustrated in fig. 21-4) which we feel, from previous basic tests, justify more detailed investigation. These include the tilt-wing concept being used in the Vought XC 142 assault transport, the tilt-duct used in the Bell X-22 aircraft, and the lift fan, used in the G.E.-Ryan XV 5A aircraft, each of which may be considered an operational prototype. It is expected that future research emphasis will shift to higher speed jet types.

Wind-tunnel and flight investigations are underway or planned as means of improving the

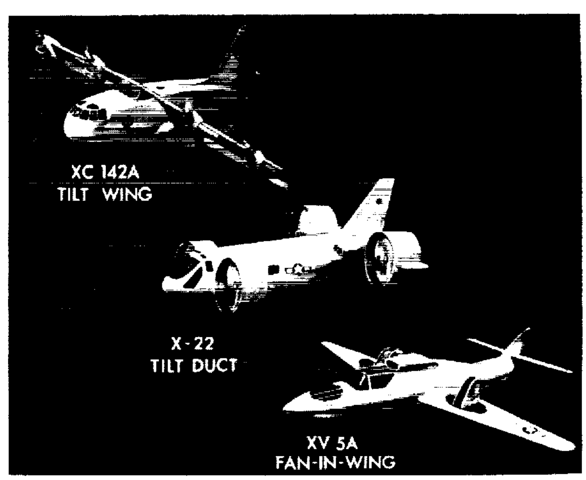


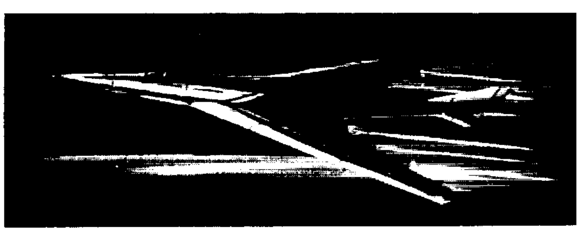
FIGURE 21-4.—Prototype V/STOL aircraft.

helicopter, which is expected to continue to have unique flight advantages. Several programs have been initiated, for example, to evaluate the nonarticulated rotor concept, aimed at reducing complexity and maintenance problems and improving flying and handling characteristics. Studies are also planned to define requirements for flying qualities and safe terminal area flight practices for operations under all weather conditions; one flight investigation is scheduled using a variable-stability V/STOL vehicle in which combinations of flying qualities, panel display information, signal sources, and approach techniques permitting transition from steep approaches to vertical touchdown under instrument flight conditions will be studied. Such studies require the expenditure of R&D funds for the research equipment and instrumentation to accomplish the task.

SUPERSONIC TRANSPORT

The current activity regarding a Government-sponsored program leading to the development of a commercial supersonic transport is well known. The French and British are jointly working toward the development of a Mach number 2.2 transport; the thinking in this country tends to a Mach 3 aircraft. This is technically more difficult but holds greater long-term promise.

The NASA is carrying out research in support of the supersonic transport, both in-house and through contracts. The important areas of research are shown in figure 21–5. For several years we have had underway aerodynamic research aimed at developing concepts which have the aerodynamic efficiency and stability and control required of an economical airplane. The development of a suitable power plant is a major problem but one in which the NASA has not played an active role. One of the important operational problems is the sonic boom produced at ground level when a supersonic aircraft passes overhead. As a consequence of past research we have established approximately altitude limits at which a supersonic transport must fly to prevent undesirable booms. Current research is aimed at more accurate predictions of boom pressures and means for alleviation of the undersirable effects. Another area of operating-problems research which is undergoing an expansion is the attainment of the flying and handling characteristics which will be acceptable to the pilot particularly in the approach and landing and take-off flight regimes.



- **CONFIGURATION STUDIES**
- **SUPERSONIC POWER PLANTS**
- **OPERATIONAL PROBLEMS**
- **MATERIALS**
- **STRUCTURES**

FIGURE 21–5.—Research areas in support of the supersonic transport.

Because of aerodynamic heating the supersonic transport must be made of materials to withstand temperatures of 500° to 600° F. An extensive program is underway to screen the many potentially useful metals for those which show the most promise. Concurrently, long duration tests of these materials are being made to assure that the metals selected will perform reliably over the estimated 30,000-hour life of the aircraft. The utilization of new metals which are characteristically heavier than aluminum alloys requires advances in structural efficiency. This is the type of development which can best be done by industry and is being done now through sponsored research by NASA and other agencies.

Because of aerodynamic heating the supersonic transport must be made of materials to withstand temperatures of 500° to 600° F.

Configuration studies are typical of NASA work. During the last few years we have conducted numerous subsonic, transonic, and supersonic wind-tunnel studies at the Langley and Ames Research Centers on generalized airplane models to evolve configurations having good supersonic-cruise characteristics with satisfactory lower speed characteristics for the off-design (take-off, climb-out, descent, and landing) flight phases. During the last 2 years, a major part of this effort has been concentrated on configurations considered feasible for the supersonic commercial air transport or "Scat" airplane. Lift, drag, static and dynamic stability, and control characteristics have been obtained for a wide variety of models. Four of the more promising Scat configurations which we have studied are shown in figure 21–6. Scat 17, which is a design concept somewhat similar to the B–70, and Scat 4 are fixed-wing designs. Scat 15 and 16 utilize variable-sweep wings, intended to provide optimum characteristics over the whole operating speed range. Much of our background on the variable-sweep concept for the transport evolved from earlier studies of the technical feasibility of a variable-sweep tactical-fighter aircraft; this concept is now incorporated in the design of the F–111 fighter, to be built by General Dynamics.

To aid in directing future NASA supersonic transport research, engineering studies are now being conducted by Boeing and Lockheed; it is intended that these studies will determine the overall feasibility of using any of these four configurations for the transport mission and indicate possible additional research problem areas for NASA investigation. The studies were awarded following a request for proposals to industry and NASA evaluation of the proposals submitted. It is expected that the results of the research investigations suggested by the industry evaluation will be of particular value in the eventual design of the U.S. supersonic transport, even if the final configuration differs substantially from any of the four.

R&D funds will also be used to support continuing research for the supersonic transport program through the purchase of complete wind-tunnel models of considerable sophistication for dynamic and static tests of the promising design concepts as well as for large-scale inlets, exits, and control systems. Contract funding also covers instrumentation for flight studies of supersonic transport operations using available aircraft to simulate the supersonic transport.

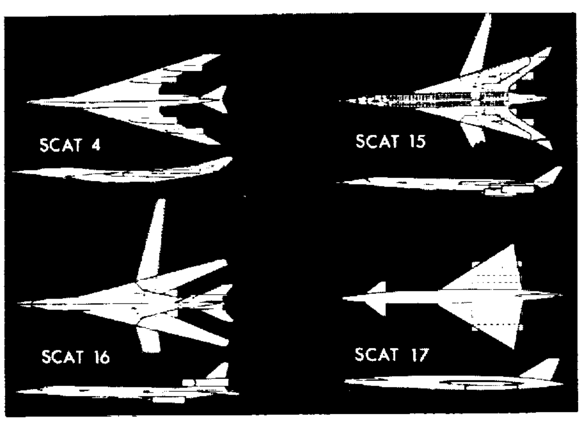


FIGURE 21–6.—Promising supersonic transport concepts.

HYPERSONIC AIRCRAFT

The third category of aircraft is the hypersonic airplane. This is really far out and will in all probability require at least 5 to 10 years of intensive research. With the X–15 airplanes we have explored the lower range of hypersonic flight for flight times measured in minutes. The attainment of long-distance flights at higher speeds will require major technological advances in numerous fields.

Figure 21–7 lists some of these technological areas. In the field of aerodynamics both theoretical and wind-tunnel studies are underway to establish feasible concepts and configurations. Some of these are aimed at ways of alleviating the fantastic aerodynamic heating, others at ways of improving range, aerodynamic efficiency, and stability and control.

The interests of practicality place some stringent limitations on the weight of the airframe for a hypersonic airplane. The airframe weight of our current subsonic jets is in the neighborhood of 20 percent of the overall weight. For the hypersonic airplane we must preserve this percentage despite the use of refractory metals needed to withstand 3,000° F temperatures on the outside and protect perhaps liquid hydrogen fuel on the inside. We are just getting started on this problem.

The hypersonic propulsion system deserves special mention. Rockets will produce sufficient thrust for hypersonic speeds but for continuous

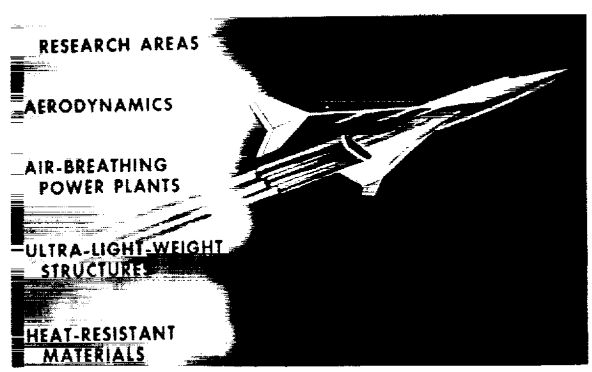


FIGURE 21–7.—Hypersonic aircraft research areas.

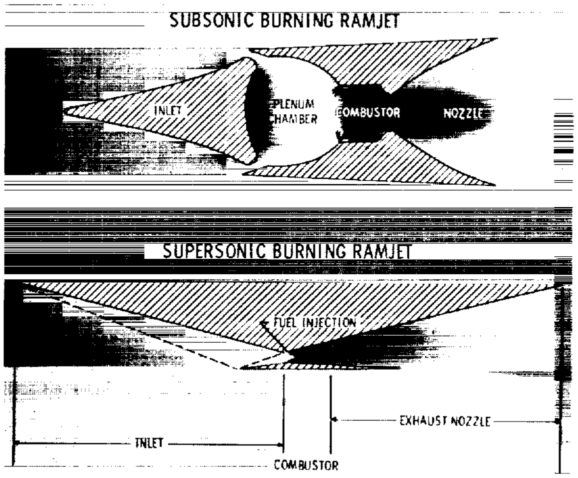


FIGURE 21-8.—Types of ramjet engines.

efficient flight, air-breathing engines are difficult to excel. The question of what part air-breathing propulsion, which offers high specific impulse, should play in hypersonic flight is now being reviewed. Initial work conducted in this field appears very promising, at least up to Mach numbers of 10 to 12.

Above about Mach 3 or 4 and on out to orbiting velocities of about Mach 25, the ramjet engine seems to be the most promising. Two types of ramjets are shown in figure 21-8—the subsonic-burning ramjet for operation up to Mach 8 and the supersonic-burning ramjet for operation from Mach 6 to 25. For the subsonic-burning ramjet, ram air is compressed at high speeds in the inlet, then slowed down in the diffuser or plenum chamber to permit subsonic burning, then expanded in the nozzle. In the supersonic-burning ramjet, ram air is slightly compressed in the inlet, but in this case fuel is added and burning is conducted at supersonic speeds and finally the exhaust products are expanded in the nozzle.

Subsonic-burning ramjets generally drop out of consideration above about Mach 8 because of excessive temperature and pressure, and the exhaust-nozzle recombination problem.

However, with the supersonic-burning ramjet engine we no longer have to operate at such high temperatures and pressures and a number of propulsion experts believe that the recombination problem in the exhaust nozzle may not be as serious as we first thought. Experimental verification of the recombination phenomena over a range of pressures, temperatures, and fuel-air ratios is required in order to determine realistic performance levels expected from exhaust nozzles of hydrogen-fueled hypersonic ramjets. This work is currently being studied within NASA along with hypersonic inlets and supersonic combustion but requires industry assistance for conceptual design studies of air breathing booster systems and rocket-model flight tests to validate data being generated by wind-tunnel research.

This paper has presented a board-brush picture of NASA aeronautical research. The several important research areas discussed indicate some current technological bottlenecks where industry aid is required to keep our aeronautical research program moving. In summary, specific program areas where the present NASA in-house aeronautical capability requires support from industry are: advanced propulsion concepts (both supersonic and hypersonic), engine noise, operations research, and the development of research equipment to aid in studies of all weather capabilities and visual displays.

22 Advanced Space Vehicle Research and Technology

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The space vehicle research and technology program covers a broad range, as indicated by the following areas of activity given in figure 22–1.

ADVANCED SPACE VEHICLE CONCEPTS

SPACE VEHICLE AERODYNAMICS

ENVIRONMENTAL FACTORS AND TECHNOLOGY

SPACE VEHICLE STRUCTURES

DESIGN CRITERIA

VEHICLE TECHNOLOGY FLIGHT EXPERIMENTS

FIGURE 22–1.—Space research and vehicle technology program.

Figure 22–2 shows the scope and program funding for fiscal year 1963.

Current funding for the space vehicle research and technology program is $39,194,000, of which approximately 75 percent is spent on contracts with industrial firms for professional services and for procurement of flight articles and laboratory equipment to support research and technology activities. The upper half of the figure indicates that approximately $18.5 million are distributed in the various subprogram areas involving both research disciplines and vehicle systems studies. The vehicle technology flight projects are shown in the lower half of the figure and have been allocated approximately $20 million for the current fiscal year. Practically all the flight projects are carried out under contracts with industry. It is estimated that the funding level for fiscal year 1964 would be approximately 30 percent higher on the basis of the President's budget request recently submitted to the Congress.

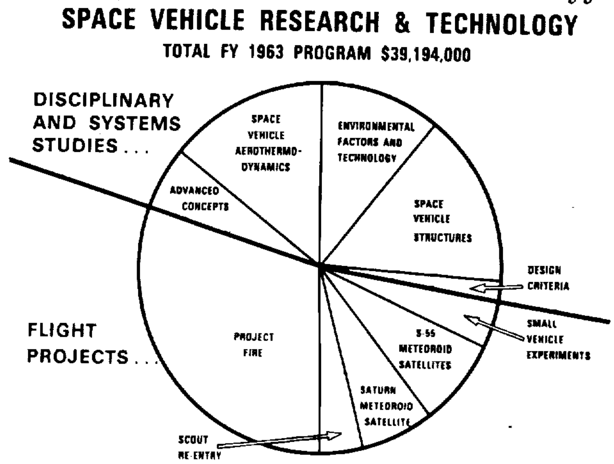

FIGURE 22–2.—Funding of space vehicle research and technology for fiscal year 1963.

ADVANCED SPACE VEHICLE CONCEPTUAL STUDIES

Applied research programs should be based on realistic appraisals of future space missions to insure that funds and other resources are used wisely. It is necessary, therefore, that operational aspects of future missions, along with new spacecraft and launch vehicle concepts, be studied carefully. The three main areas of activity, shown in figure 22–3, are:

Earth orbital operations
Advanced lunar missions
Exploratory missions to the planets

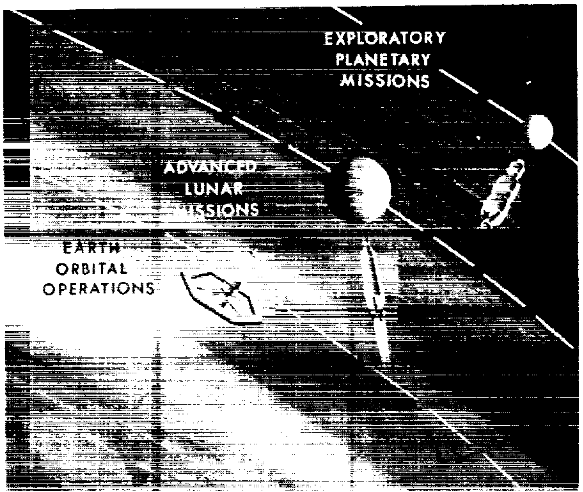

FIGURE 22–3.—Advanced space vehicle concepts.

Each of these three areas poses special problems in design of space vehicles. For example, manned exploration of the planets confronts us with quite different technical problems than those of manned orbital missions or missions to the moon. Obviously, vehicles for planetary missions will be much heavier and must operate effectively for much longer periods of time. The date on which the planetary mission is undertaken is also of great importance.

Advanced conceptual studies currently underway include earth-orbiting space laboratories; recoverable boosters; earth-lunar transfer vehicles or ferries; and large advanced launch vehicle systems with spacecraft capable of entering planetary atmospheres and returning to the earth at velocities of 45,000 feet per second or greater. These studies have defined a number of important long-range problems in research and technology, and have indicated that some future missions may require radically new vehicle configurations and systems.

SPACE VEHICLE AEROTHERMODYNAMICS

The major areas of activity in space vehicle aerothermodynamics are indiciated on the left side of figure 22–4. The picture on the upper right-hand side of the figure is representative of the configurations being studied to develop the technology for successful entry into the earth's atmosphere at interplanetary speeds, and for entry into the atmospheres of other planets.

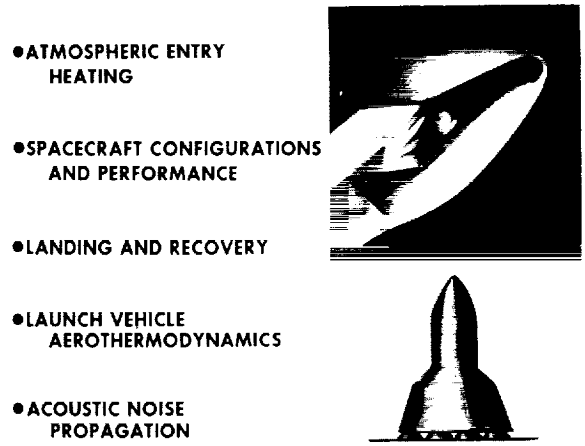

FIGURE 22–4.—Research areas in space vehicle aerothermodynamics.

Applied research will continue toward further development of lifting-body vehicles for a variety of space flight missions. In addition, promising devices such as steerable parachutes, paragliders, rotors, retrorockets, and arrangements with extensible wings and inflatable afterbodies are being studied. Configuration studies in ground-based facilities are being augmented by flight research on simplified manned vehicles to devise means of providing acceptable flying qualities for spacecraft capable of horizontal or tangential landings on the earth or other planets.

The sketch on the lower right side of the figure is representative of the many launch vehicle configurations being studied. These studies include trajectories and staging, loads and forces, hinge moments of gimbaled rocket nozzles and flow phenomena in regions of rocket exhaust, and wings or other lifting devices for returning the launch vehicles of the future to the launch area.

The noise generated by large rocket engines will become an increasingly severe problem. Studies of the noise field around the Kiwi nuclear rocket have been initiated. Analytical and experimental studies will be extended on the generation and propagation of noise from both chemical and nuclear rockets, and on the effects of noise on space vehicles.

ENVIRONMENTAL FACTORS AND TECHNOLOGY

Space vehicle design becomes increasingly difficult for future missions because of the long duration of exposure to the hostile environments of space which are today only partially defined. The major areas of activity in the environmental factor and technology program are indicated on the left-hand side of figure 22–5.

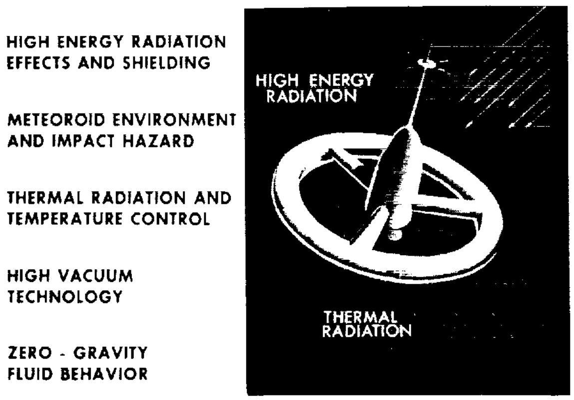

FIGURE 22–5.—Research areas in space environmental factors and technology.

In the high-energy radiation and shielding area, primary emphasis is placed on studies of the effects of electron and proton bombardment on spacecraft components and materials, and both passive and active means for shielding men and sensitive equipment from charged particle radiation. Since all space vehicles will, to some degree, be exposed to high-energy radiation fields, a wide variety of problems require theoretical and experimental investigation.

Activities on meteoroid environment and impact hazard are concerned with defining and assessing the statistical nature of the space debris, and the utilization of ground-based and flight techniques for simulating meteoroid characteristics. New techniques for particle acceleration, new or improved theories for hypervelocity impact, and effective means for observing and recording micrometeoroid characteristics are constantly being sought.

The control of spacecraft temperature becomes increasingly difficult as spacecraft become more complex and as their variation in distance from the sun increases. Space vehicle coatings will be studied, as well as mechanical and electronic techniques for altering the heat balance of space vehicles. Methods for accurately simulating the solar spectrum and for modeling techniques are required.

The effects of very low pressure in space require extension of our capabilities in high vacuum technology. Improved techniques or new methods are needed for reaching, measuring, and maintaining vacuum conditions lower than 10^{-13} millimeters of mercury in facilities of useful size.

An improved understanding of zero-gravity fluid behavior is important with regard to fuel storage, tank design, fuel pumping and engine restart, and fuel container heat-transfer problems. Of immediate aid would be the formulation of better theoretical explanations of the zero-gravity effects observed to date.

SPACE VEHICLE STRUCTURES

Future space vehicle structures will be larger and heavier, and they will be required to operate for longer periods of time than those required for present approved programs. Aggressive research will be required to maintain weights at reasonable levels and to predict structural behavior with greater accuracy to insure reliability under the severe environments and complex loading conditions which space vehicle structures will experience.

Unfortunately, all aspects of space conquest are not on the positive side. In considering protection from space hazards, we should not expect conventional structures to satisfy the unconventional requirements imposed on space vehicles. The space vehicle structures of the future will certainly challenge the resourcefulness and ingenuity of the designer and will require a significantly broader based technology than exists today.

Future space vehicle structures will be expected to provide *simultaneously* (fig. 22–6): adequate strength; stiffness; tolerance to temperature; and integrity against all space hazards.

Earlier experience with the first three areas indicated that the desirable solution was to separate the load-bearing and temperature-bearing abilities of a space vehicle structure. However, when meteoroid protection, high-energy radiation shielding, tolerance to vacuum conditions, and thermal control of radiation effects are required, it appears more fruitful to com-

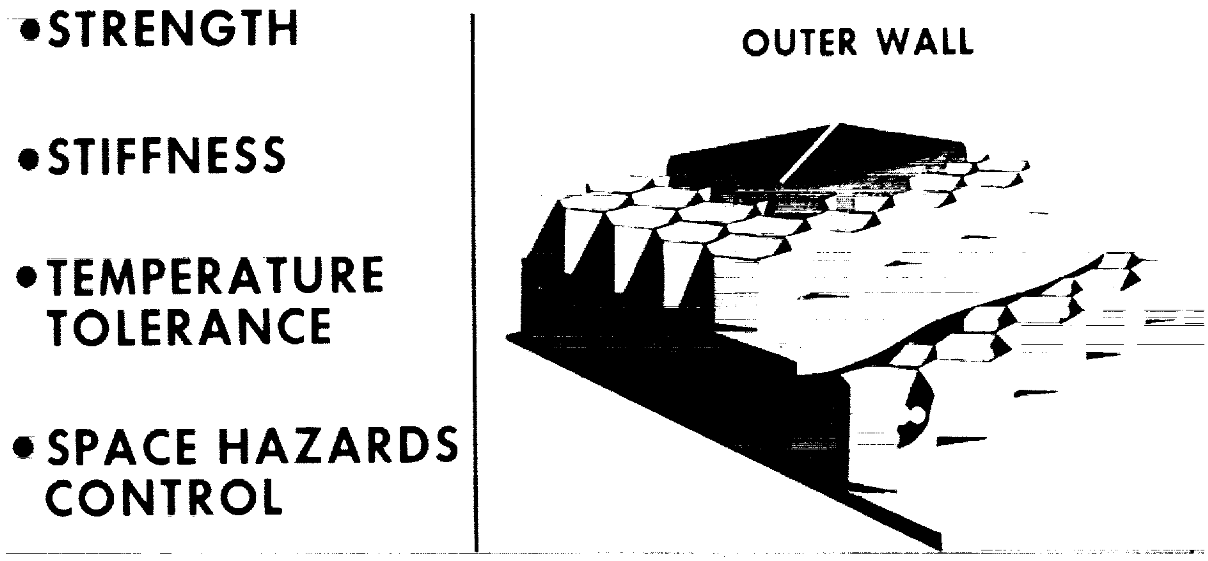

FIGURE 22-6.—Multifunctional space vehicle structure.

bine the necessary protective features into a single structural wall. The diagram on the right (fig. 22-6) illustrates this idea. The outer layer (shown on top) is a charring ablator for temperature control; it also provides limited protection against radiation and meteoroids. The inner wall provides strength, along with additional means for temperature control. A self-sealing mechanism, in this case honeycombs filled with hollow rubber spheres, provides integrity of the pressure vessel. This diagram is only conceptual and is used merely to indicate a possible trend in space vehicle structures.

In a similar vein, figure 22-7 shows several unconventional aspects of spacecraft design.

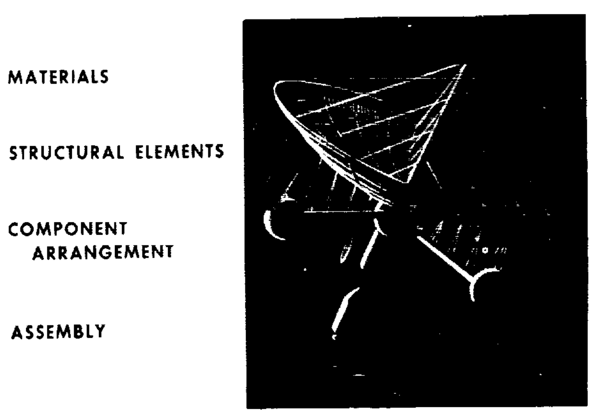

FIGURE 22-7.—Unconventional aspects of spacecraft design.

Such odd characteristics result from relaxed constraints on configurations in cases where aerodynamic forces are no longer a consideration. Here, the structural loadings are peculiar only to the space flight phase of a mission.

Freedom from configuration constraints should enable design of vehicles making efficient use of unusual materials and structural elements, such as (for example) cables and trusses. Essential structural components might also be positioned so as to improve mass distribution and temperature control.

Finally, the structural designer may have a choice of methods of spacecraft assembly or erection in space. These approaches are appealing from the standpoint of their influence on the size of future launch vehicles.

SPACE VEHICLE TECHNOLOGY FLIGHT EXPERIMENTS

The Advanced Research and Technology Program includes a number of carefully selected flight experiments, each directed at the objectives indicated as follows:

(1) Reentry
  (a) Scout-launched reentry experiments
  (b) Project Fire
(2) Meteoroid Hazard
  (a) S-55 satellites
  (b) Saturn-launched meteoroid satellites
  (c) Recoverable meteoroid probe

- (d) Artificial meteor experiments
- (3) Small Vehicle Flight Experiments
  - (a) Behavior of cryogenic fluids at zero-g
  - (b) Wind shear measurements
  - (c) Solid fuel thrust vector control
  - (d) Radio attenuation measurements
  - (e) Horizon detection and attitude stabilization

The major flight projects fall in the areas of hypervelocity atmospheric entry, and meteoroid hazard; we also are conducting a number of experiments using small launch vehicles.

One reentry experiment, Project Fire, is shown in figure 22–8. Project Fire consists of an Atlas vehicle, a velocity package using the Antares or Scout third-stage motor, and an extensively instrumented payload weighing 185 pounds. The payload is accelerated to a reentry velocity of 25,000 miles per hour or 37,000 feet per second. The primary objective of the project is to obtain critical data on the radiative and convective heating in the true flight environment. Attention in a follow-on program would be given to heating phenomena which occur at the considerably higher reentry speeds of interplanetary flight.

Flight experiments to study the meteoroid hazard are shown in figure 22–9. The current status of knowledge concerning the meteoroid hazard is such that the uncertainty in weight of structural materials required for protection of spacecraft is represented by a factor of 20. Of necessity, we have resorted to flight experiments to provide engineering information on meteoroid penetration. An S–55 satellite is shown on the upper left in the figure. One S–55 spacecraft, designated the Explorer XVI, was launched by a Scout rocket on December 16, 1962. The orbital life is expected to be more than 1 year. The vehicle is performing well, and very useful data are being obtained.

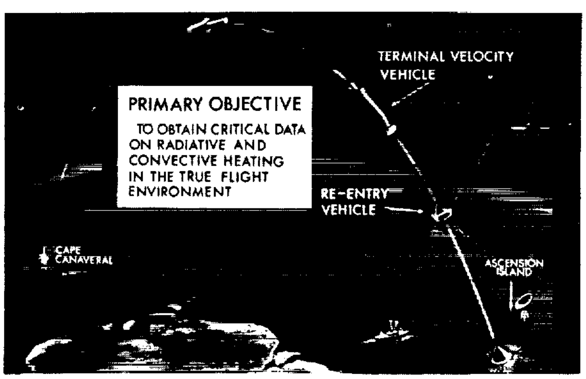

FIGURE 22–8.—Project Fire, a reentry flight experiment at 25,000 miles an hour.

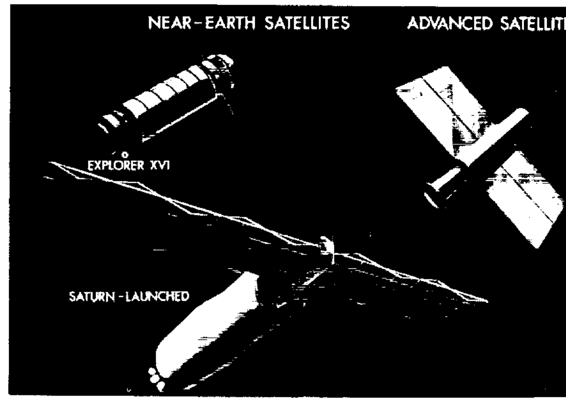

FIGURE 22–9.—Meteoroid hazard studies.

A meteoroid experiment which will be launched on Saturn vehicles SA–8 and SA–9 has just been approved. The objective of this program is to expose instrumented surfaces of about 2,000 square feet to meteoroid penetration. The spacecraft, to be launched in 1964, will provide data on penetration rates for metal sheets approaching nominal space vehicle wall thicknesses.

The S–55 and Saturn-launched meteoroid experiments will provide data on the meteoroid hazard in the vicinity of the earth. There also appears to be a need for similar information about cislunar space and space near the moon to determine the nature of the meteoroid hazard for manned lunar missions. An advanced meteoroid satellite program to provide such information is being considered.

SPACE VEHICLE DESIGN CRITERIA

Information resulting from research and technology programs must be formulated into design criteria to insure prompt application to vehicle design in an acceptable and uniform manner. We are undertaking the compilation, correlation, and assessment of the state of the art of space vehicle research and technology, and the preparation, documentation, and updating of general design criteria standards. The effort encompasses the establishment of standard models of the environment within which space vehicles operate, and of criteria for the design of structures, propulsion systems, and guidance and control systems. The initial or preliminary criteria are planned for completion during the latter part of 1963. As the technology changes, these documents will be updated and expanded.

23 Research and Technology in Chemical Propulsion and Space Power Generation

JOHN L. SLOOP

Director, Propulsion and Power Generation, Office of Advanced Research and Technology

The role of the Office of Propulsion and Power Generation is to accomplish the necessary research and technology for the development of advanced propulsion and space power generation systems using chemical or solar energy. The work is done in NASA centers (including JPL), in universities, and in industry, with industry getting about 70 percent of the funds. For fiscal year 1963, about $21 million will be spent in research and development—the split being about $13 million in chemical propulsion and $8 million in space power generation. We are asking the Congress for over $34 million in the coming fiscal year for both these programs.

In chemical propulsion, our range of interest is broad, as shown in figure 23–1. We are interested in engines that use liquid and solid propellants and hybrids that use a combination of both, rocket engines that use air (or planetary atmosphere) for thrust augmentation, and others that use solar energy to heat the working fluid. We are working on the chemistry of the propellants for these engines, on combustion phenomena, and on the fluid dynamics of the propellants from the tanks through the expansion of the combustion gases in the nozzle. We are obtaining better heat transfer data and studying high temperature materials and cooling techniques to contain the hot gases.

Chemical propulsion systems for space exploration can be grouped for convenience as: engines for take-off from the earth's surface, engines for upper stages of boosters, engines for spacecraft propulsion, and small space engines for attitude control, maneuvers, stage separation, man-mobility in space, and so forth. Some advanced engines in these classes are depicted in figure 23–1. The engines on the left, from top to bottom, are: a solid rocket motor, a hybrid motor, and a small space engine; on the right are: a large booster engine, an engine with air augmentation, and a schematic diagram of a spacecraft engine.

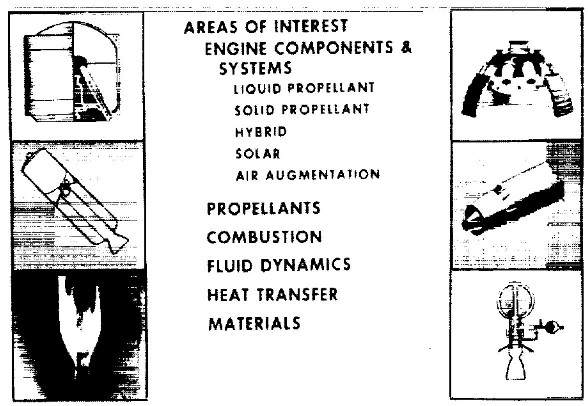

FIGURE 23–1.—Chemical propulsion research interests.

Our research and technology program for these engines ranges from analytical and experimental research to feasibility demonstrations of advanced propulsion systems.

Engines now in use or in development for earth take-off have thrusts up to 1.5 million pounds and five of these will be clustered for Saturn V. The next step in booster engine size will probably be on the order of 20 to 30 million pounds of thrust or higher. For these large thrusts, new engine concepts are needed. Figure 23–2 shows the scale-up of conventional and advanced concepts of large engines. The first

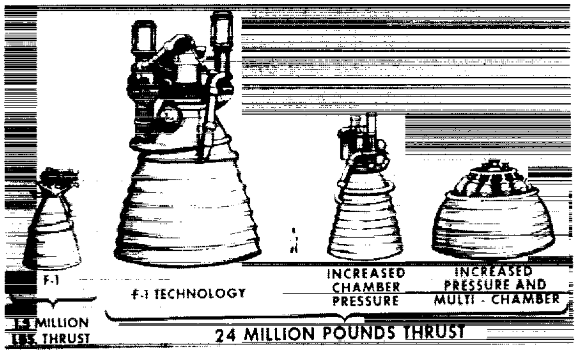

FIGURE 23-2.—Scale-up of conventional and advanced engine concepts.

engine on the left is the F-1 engine having 1.5 million pounds of thrust which represents the present technology. The scale-up of this technology to engines, say, in the 24-million-pound-thrust size results in an excessively large engine—one over 50 feet high, as shown by the second engine. The engine size can be reduced to something more reasonable by increasing the operating pressure several-fold as indicated by the third engine. Accordingly, work is underway now and will continue for some time on the technology of using high operating pressures. We must learn how to make better pumps and turbines to produce high propellant pressures, how to devise flow components and systems to handle high pressure fluids, how to ignite and burn the propellants stably at high pressures, and how to keep the engine cool under the higher heat load. We want to conduct experiments with new nozzle concepts, some with air augmentation, that hold promise of more efficient operation in the earth's atmosphere and which allow more compact engine envelopes. An illustration of an engine with such a nozzle is shown by the fourth engine. In this case, a multitude of combustors feed into a common nozzle. We know little about these concepts, especially at large sizes, how they will operate over a range of normal and abnormal conditions, and how to obtain thrust vector control with them. All these must be examined. Oxygen-hydrogen is of considerable interest in this application. If oxygen-kerosene is used it may be doctored with additives to improve ignition and combustion characteristics.

We are also doing work related to the use of large solid rocket engines and hybrid types for earth take-off. NASA is working in close cooperation with the Air Force in a joint NASA-DOD solid engine technology program. There is much to be done on giant engines for earth take-off.

Engines for upper stages of boosters range from a few thousand pounds thrust for small boosters to the 200,000 pounds thrust of the J-2 engine for the advanced Saturn. A large hydrogen-oxygen engine now in development, the M-1, has a thrust of over a million pounds. Upper stage engines generally complete their operation within minutes to a few hours after launch, and hence, boiloff of propellants or possible micrometeoroid damage to tanks are not major considerations. Most of these engines will use hydrogen and oxygen. Future trends for these types of engines will probably be toward higher operating pressures and new nozzle concepts similar to those previously discussed. We are interested in propellant combinations with higher specific impulse than hydrogen and oxygen or that offer some other advantage. Those under consideration include hydrogen-fluorine and propellants containing light metals.

Engines for spacecraft—liquid, solid, or hybrid—must meet the stringent requirements imposed by the environment of space. In some cases, they must ride dormant or coast for long periods of time. Variable thrust and multiple starts are needed for most missions. This application places a premium on high-energy propellants, storability in the space environment, and high propellant density. More work is needed on performance, cooling, and storability characteristics of high-energy propellant combinations in the space environment as well as on the shielding necessary to safeguard the propellant case or tanks against micrometeoroid penetration.

Small space engines must be compact and versatile to meet the demands for attitude control, midcourse maneuvers, and so forth. They are generally called on for multiple operations spread over long periods of flight. To simplify fuel storage aboard a spacecraft a small space engine should use the same propellant as the main propulsion system. Small engines are more difficult to cool than large ones and it is more difficult to obtain good performance from them.

Figure 23-3 shows an advanced propulsion concept that could apply to spacecraft propulsion or small space engines. This is more to illustrate the work areas than to indicate an

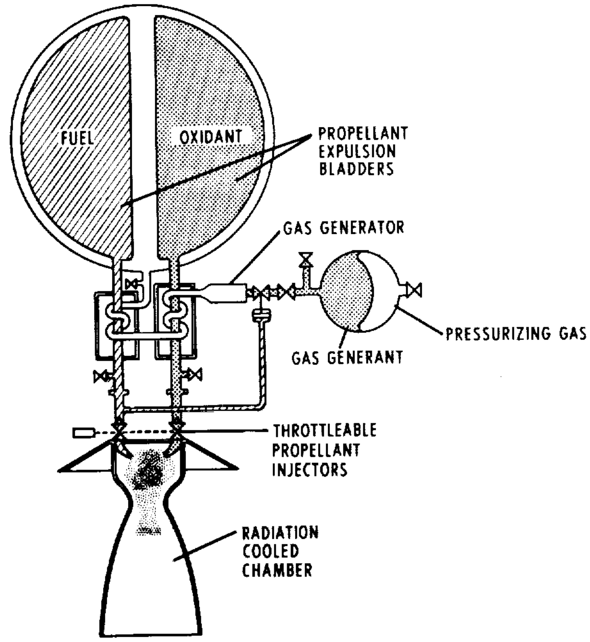

FIGURE 23-3.—An advanced propulsion concept.

optimum design. It uses propellant expulsion bladders, a gas generator with heat exchanger, throttleable injector, and radiation-cooled thrust chamber. It must start in any attitude under zero-g conditions after weeks of flight and be capable of numerous operations. Such requirements call for intensive work in the areas mentioned.

Work in combustion is linked very closely to determining the promise of new propellant combinations. Another combustion area of great concern is combustion oscillations. These are pressure fluctuations in the combustion chamber which greatly increase heat transfer and can destroy the combustion chamber if allowed to continue. This is probably the greatest single problem in rocket engine development and we want to increase our efforts both in basic studies of these complex phenomena and in engineering studies to devise techniques for controlling or eliminating these oscillations.

Figure 23-4 shows some of the areas where work is underway or planned in the field of space power generation. These are solar cells, thermionics, thermoelectric systems, magnetohydrodynamics, solar dynamic or heat engines, batteries, fuel cells, engines using chemical reactants, power conditioning and control equipment, solar collectors or concentrators, and thermal energy storage. Some of these are depicted in the figure. On the left, from top to bottom, are: a battery, a fuel cell, and a chemical engine; on the right are: a solar cell array, a thermionic system, and a solar dynamic system.

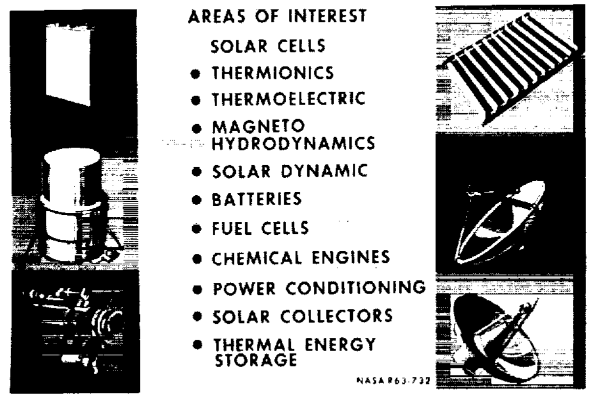

FIGURE 23-4.—Solar and chemical power generation.

In solar cells, we wish to do more work to increase their efficiency over a temperature range, to increase their resistance to radiation, and to decrease their cost and weight. We are interested in a number of types including those that can be made as thin films. Thin film solar cells, such as that illustrated in figure 23-5, hold promise for reducing weight and allowing photovoltaic cells to be mounted on flexible surfaces. This makes possible the carrying of large solar cell areas in a compact package for unfolding in space or on the lunar surface. At present, thin-film photovoltaics have very low efficiency, and work to improve their efficiency

FIGURE 23-5.—Flexible thin-film, cadmium sulphide, photovoltaic cell.

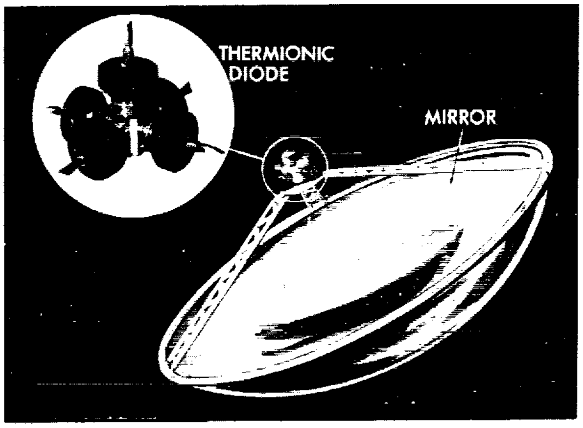

FIGURE 23-6.—Solar thermionic power systems.

and fabrication techniques for systems in the multikilowatt levels is one of our program goals.

Work is underway on thermionic power converters such as that illustrated in figure 23-6. The thermionic system converts heat directly into electrical energy and does not have the radiation problem of solar cells. The essential elements of the thermionic system include a solar collector, an array of thermionic diodes, and associated energy storage and power conditioning equipment. The insert is a photograph of an array of five diodes. Work at the Jet Propulsion Laboratory is proceeding on a lightweight, thermionic power generation system which has a design goal of approximately 135 watts at Mars, a 1-year life, and a weight of the collector-conversion unit on the order of 30 pounds. Power generation by this method is still in its infancy and much technology work is needed for this promising method.

Work is underway on the technology of a multikilowatt solar power system using turboalternators for power conversion. It consists of a solar concentrator, a boiler and heat storage unit, a turbogenerator and assoicated components, pumps, and radiators. The system under investigation uses mercury vapor as the working fluid. Work at present is on a 3-kilowatt power unit although this type of system will probably prove useful for power levels to 30 or more kilowatts.

Batteries are the primary method used today for energy storage for power generation. These are alkaline electrolyte cells using such electrode combinations as nickel-cadmium, silver-cadmium, and silver-zinc. Program goals are to get higher energy per unit weight, lower sensitivity to thermal environment, and increased life (both in standby and discharge-recharge cycling). Some work on new systems has indicated theoretical energies up to 25 times as great as nickel-cadmium and work is needed to explore these potentialities.

Fuel cells are capable of high-energy conversion efficiencies (50 percent or higher), are compact, and have few or no moving parts. Apollo and Gemini spacecraft will use fuel cells with hydrogen and oxygen as the reactants. Work is underway on fuel cells operating at low temperatures using liquid or solid membrane electrolyte, intermediate temperatures using molten caustic, and high temperatures using molten salts or solid oxides. Regenerative fuel cells are of particular interest for long-duration missions. Work is underway on pulsed operation of fuel cells to reduce system weight and extend operating life and on biochemical fuel cells using human waste.

Chemical engines are useful for missions of a few hours to a few days or for intermittent use for longer periods of time. There are a number of different engine types, piston and turbine, and several cycles that may be useful for space applications. We have work underway on a piston engine using hydrogen-oxygen. Major problems are lubrication and cooling, and oxygen injection. We are interested in using the same reactants as used for spacecraft propulsion, the major one at present being nitrogen tetraoxide and a hydrazine mixture.

It is hoped that these brief comments on propulsion and power generation will give a perspective into the kinds of work NASA is doing now and is planning for the future with the help of industry.

24 Electronics and Control

ALBERT J. KELLEY

Director, Electronics and Control, Office of Advanced Research and Technology

The Electronics and Control Directorate is responsible for program management and policy direction of NASA sponsored research and advanced technological development in the fields of electronics and control which will evolve techniques and prototype subsystems responsive to NASA's approved and envisioned future requirements. The Electronics and Control Program encompasses the disciplines of the following functional areas:

(1) *Guidance and Navigation*—Determining, predicting, and directing a vehicle's position along a flight path or trajectory.

(2) *Control and Stabilization*—The control of a vehicle along and about the flight path.

(3) *Communications and Tracking*—The transmission of commands to and the recovery of data from an aerospace vehicle.

(4) *Instrumentation and Data Processing*—The detection, generation, and measurement of information or phenomena, and reduction of this information to intelligible and useful forms.

In addition to the normal functions of NASA program management, this Directorate, on a continuous basis, analyzes the state of the art together with projected needs in order to establish research and technological requirements. These requirements will be translated into those investigations and advanced developments which can be expected to yield the maximum benefit in support of NASA objectives and future systems.

The importance of electronics in space is quite apparent. Electronics and its associated disciplines constitute the brain and nerves of space vehicles. It is estimated that about 70 percent of our major spacecraft dollars go into electronics, not to mention the vast amount of design, testing, and checkout effort. The success of electronics is, in fact, a major factor in overall mission success since a dead or unintelligent vehicle, no matter how successful its launch or trajectory, is useless if it cannot measure data and send them back to earth.

Advanced research and technology efforts in the guidance and navigation of spacecraft, launch vehicles, and advanced flight vehicles are of prime importance and in this discussion two examples are presented in which increased research emphasis is required: rendezvous sensors and horizon sensors. Part of our guidance advanced research and technology program is slanted in the direction of determination of future research and development requirements as well as the techniques to meet those requirements.

Ideally, this should be done on some more tenable basis than novelty of technique or judgment of our scientists. There should be a more formalized way of deciding what research is worth pursuing based on an analytic methodology.

Figure 24–1 illustrates such a methodology. This Directorate is making use of this tool to determine advanced rendezvous sensor research requirements to identify parameters which are best suited to technological exploitations. Our technological problems all stem from known or

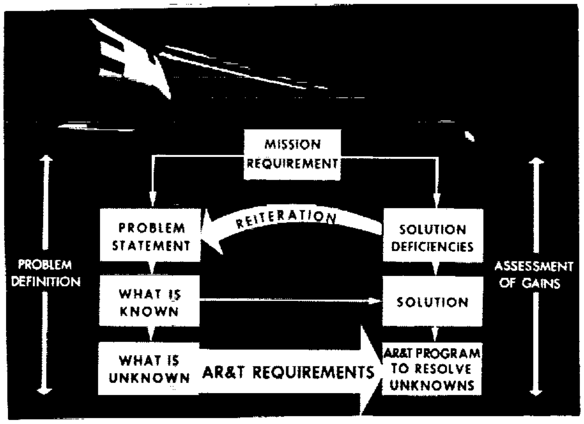

FIGURE 24-1.—Rendezvous sensor study.

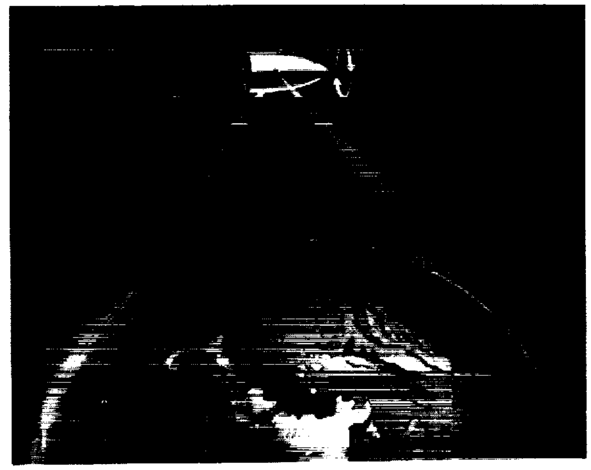

FIGURE 24-2.—Project Scanner.

anticipated mission requirements. Given the requirement, a statement of the problems to be solved in any area, such as rendezvous guidance, is derivable. From the problem statement, descriptions of the "knowns" and "unknowns" are developed. The known factors contribute directly to solutions. However, the unknown factors constitute the requirements for our long-range research and development programs. None of the possible real life solutions will ever be without deficiency. Comparison of the mission profile with the solutions permits estimation of the solution deficiencies. Completing this cycle several times in a reiterative fashion brings about a convergence on the research and development requirements and on predictably optimum solutions. At its poorest, the method should permit estimates of the result of any course of action before this action has fully committed us to an expensive program.

Many of our technology programs can be upgraded by increased knowledge of the physical phenomena involved. One example of this is in the area of navigation inputs derived by horizon scanning in the vicinity of a planet with an atmosphere.

It is feasible to design a sensor which can track the electromagnetic discontinuity between the space background and the planetary disk, and such sensors have actually been used in the guidance systems of flight vehicles. However, in the case of many planets, such as earth, our knowledge of the effects of the perturbing influence of the atmosphere and the seasonal and daily differences in earth's radiation are incompletely known. As a result, otherwise adequate designs of horizon scanners such as those used by the astronauts on the Mercury program can suffer large errors in the determination of the vertical. In Mercury, vertical errors as large as 30° were noted in the vicinity of tropical storms. Studies of the structure of the atmosphere have allowed us to predict that certain portions of the ultraviolet and far infrared spectrum may present a more stable horizon than the 3 to 5 micron infrared region usually used. These theoretical studies will require experimental confirmation.

In order to improve our knowledge of the phenomena involved, we have established Project Scanner, a program of several vertical probe rocket firings, using inexpensive vehicles to carry aloft advanced instruments. (See fig. 24-2). The instrument package is planned to gather 350 data points per flight in each of several spectral bands utilizing sensors with about 0.03° resolution. The first flights using crude instruments (3° resolution) have already been completed and data from these show some advantage in the ultraviolet band. Flights of improved instrumentation packages are programed for the first quarter of calendar year 1964. The program is under the technical direction of the Langley Research Center.

An important part of the Control Systems effort is directed toward solving the problem of predicting and evaluating manned system performance. In order to develop control systems and displays which best complement man's capabilities, the contributions of various scientific disciplines are brought to bear upon

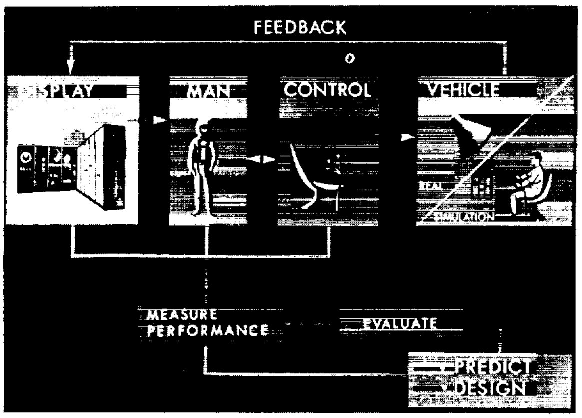

FIGURE 24-3.—Manned control systems.

this problem. Several approaches are now utilized which range from measures acquired by experimental psychologists and engineers to analytical expressions written by mathematicians. One fundamental goal of this effort is to enable the designers to tailor control systems around the man, where man is an integral part of the man-control-display loop. (See fig. 24-3.)

Flight and space simulators are powerful research tools for collecting performance measures simultaneously under a wide variety of selected and controlled conditions. Various control-display arrangements can be operated under many task constraints in an effort to determine pilot capability as it relates to the equipment which he has to aid him. Significant is some recent work at Langley Research Center. The Langley investigators found that a man could successfully control a simulated space rendezvous task with a minimum of instrumentation. The target was represented as a blinking light upon a projected star field background. Using only this visual information, pilots were able to estimate range and range rate and successfully complete the rendezvous.

The research simulation art is advancing rapidly thereby permitting modes of inquiry which were unknown only 5 years ago. Under NASA development programs, private industry and university and NASA scientists are developing such devices as star field projector displays, which the pilot views through the window of his simulated craft and by which he guides his craft via his own celestial navigation. Devices which rest upon air bearings or cushions allow nearly frictionless movement in several dimensions and permit such investigations as the significance of motion cues and the evaluation of multiaxis and single-axis controllers. As our capability to simulate a wide variety of stimuli improves, so will our knowledge of man and his capabilities improve, thereby providing better design criteria for manned flight control systems.

The Communications and Tracking Program is vitally concerned with expanding our capability to communicate, reliably and efficiently, with spacecraft making scientific explorations into the depths of space. The art of space communications and tracking are closely related, for tracking space vehicles is often a prerequisite for communications.

The advent of significantly new devices and techniques for communications will be the foundation of the future systems. Laser technology promises to open the tremendous range of the optical spectrum for man's use in communications. Since lasers are only approximately 2½ years old, a good many challenges exist which stimulate the imagination. Some examples of these are:

(1) Efficient generation of coherent optical radiation.
(2) Efficient and practical methods of modulation and detection.
(3) Detailed investigations of signal transmission characteristics as a function of range and propagation medium.
(4) Relativistic effects. For example, an electromagnetic signal reflected from a satellite will be deflected forward of the transmitter in the direction of motion of the spacecraft. If a laser is employed as the transmitter, the returned signal may, by virtue of its narrow beamwidth, completely miss the receiving antenna. The S-66 satellite, which is being configured to be tracked by lasers, has had to be designed so that the return beam is sufficiently spread out to insure reception. (See fig. 24-4.)

Another important part of our communications research program is concerned with communicating through the ionized plasmas which are created when a body enters the atmosphere at high velocities or which may be created by the exhaust products of chemical rockets. A familiar example of this situation is the communications blackout which lasted for approximately

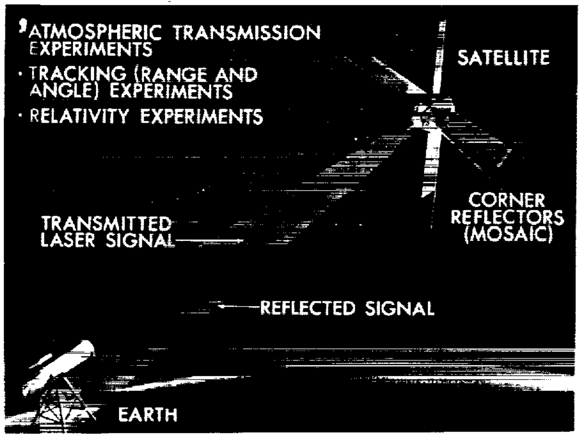

FIGURE 24-4.—Laser (optical) tracking.

4 minutes during the Project Mercury reentries. (See fig. 24-5.) The ionized plasmas act as a shield to blackout communications "completely" during this critical portion of manned flight; or, as in the case of blackout due to rocket exhaust gases, the radar altimeter could be blacked out during the critical lunar or planetary landing phase.

Significant progress has been made in evolving techniques to solve these problems. Langley Research Center has conducted materials-addition experiments under simulated conditions of reentry which indicate that communications blackout may be eliminated by injecting water into the ionized flow field when communications are required. It is planned to verify these results in a flight experiment in the near future.

Mission success of space explorations depends to a large degree on instrumentation capability. As a result, scientific instrumentation for measuring space and planetary phenomena and engineering instrumentation for monitoring space vehicle performance must supply accurate and precise data. (See fig. 24-6.) At present, raw data, as sensed by transducers measuring pressure, temperature, radiation values, and so forth, go through a variety of transformations such as amplification, modulation, and digitization prior to data transmission or data processing including storage. All these steps tend to decrease accuracy and reliability. Therefore, emphasis must be placed on transducers and sensing devices capable of providing output signals in a more convenient form better adapted for data handling.

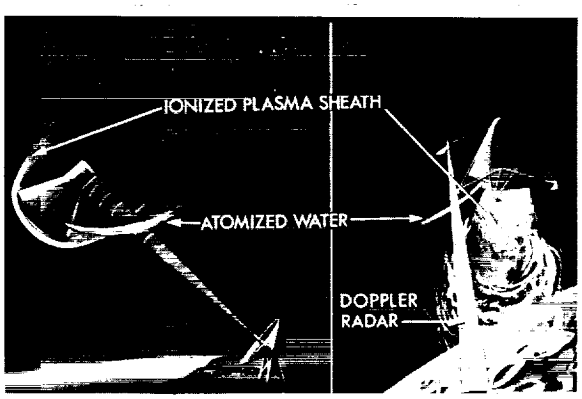

FIGURE 24-5.—Reentry communications blackout.

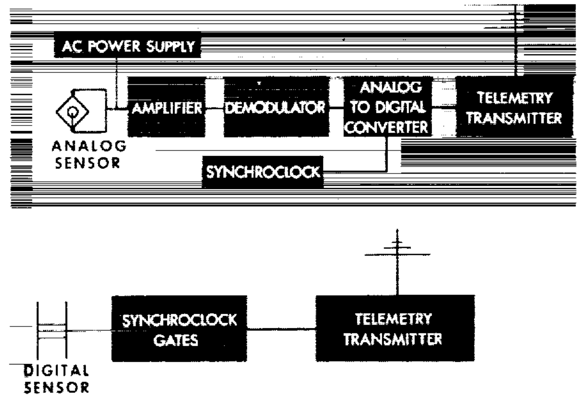

FIGURE 24-6.—Comparison of analog and digital sensing devices.

A sensing device producing an output in digital code form obviously has an advantage in that its value can be transmitted without undergoing the various conditioning steps previously mentioned. Therefore, the study and investigation of materials and techniques for achieving digital outputs from transducers is a pertinent problem requiring concentrated attention. Although several schemes are now under investigation, emphasis should be placed on new principles (including molecular electronics and solid-state transducers) to arrive at a compact and unified digital transducing device with adaptive sensing heads for measuring the various physical phenomena.

In keeping with the importance of electronics to current and future space missions, the NASA fiscal year 1964 budget requests congressional approval for funds to establish a new Electronics Research Center to be located in the Greater Boston Area. The center will have the principal function of conducting research and component technique development in communications, data processing, guidance, instrumentation, control, and energy conversion. It will serve to concentrate efforts on the advancement of these closely related fields to meet urgent requirements of our national flight programs and missions in the aerospace environment.

It is not necessary to emphasize the fact that the United States has a large, active, and capable electronics industry and it is our intention to continue to utilize it in the most efficient manner. To this end, the Electronics Research Center will provide the operating base for a competent and experienced staff of scientists and engineers well informed on the NASA requirements, and knowledgeable regarding the potential solutions and capabilities inherent in electronics and physics research. The staff at this center will play an important role in the technical direction of the increasing NASA research and development funds which are contracted to the nation's electronics industry, and thereby add assurance to the fact that NASA, industry, and the country are attaining maximum benefit from the space program dollars.

25 Biotechnology and Human Research

EUGENE B. KONECCI

Director, Biotechnology and Human Research, Office of Advanced Research and Technology

The program of the recently formed Directorate of Biotechnology and Human Research is designed not only to do human research and development for adequate life support and protective systems for man's survival in the aerospace environment but also to determine man-machine relationships adequately, and integrate them properly into the advanced aerospace systems which are envisioned in the next 10 to 20 years. A systems analysis was performed to determine the organization and program required to fulfill the mission of Biotechnology and Human Research.

The program is outlined in a systems parametric chart. (See table 25–I.) Organizationally, the Man area is administered by the Human Research Division, Man-Machine by the Biotechnology Division, and Man-System by the Man-System Integration Division.

The program involves the study of man (capacities and capabilities), man-machine (life support and protective systems, bioinstrumentation, man-machine control), and man-systems integration (human factors, systems analysis) in relation to the basic parameters of the environment, design requirements, bioengineering, simulation, ground and flight test, evaluation of performance, and advanced concepts.

A systems analysis of possible future NASA missions has been useful in establishing priorities. Some of the most critical human and biotechnology problems or unknowns which affect future manned aerospace system design are:

(1) Psychophysiology of prolonged exposure to zero or subgravity (i.e., periods of 1 month to several years).

(2) Effects on humans and design implications of space and man-made radiations.

(3) Advanced integrated life support systems designed for 1 month to several years of operation.

(4) Advanced intravehicular and extravehicular protective and locomotive systems for free space and lunar and planetary surface operations.

(5) Advances in bioengineering are needed in bionics, bioinstrumentation (especially body sensors), man-machine information handling, display and controls for psychophysiological monitoring and for all-weather manned aerospace flight.

(6) Advanced dynamic ground and flight simulation techniques and the development of human analogs.

(7) Flight, ground support, and space research personnel selection and training requirements and advanced techniques.

The overall Biotechnology and Human Research Program is managed by the headquarters Program Office in the Office of Advanced Research and Technology (OART), which contracts directly or assigns specific program areas to the centers. The centers, in turn, do the work in-house or contract it directly, with headquarters Program Office coordination. (See table 25–II.)

TABLE 25-I.—*Biotechnology and Human Research Program—Systems Parametric Chart*

	Environment	Requirements	Bioengineering	Simulation test and evaluation	Advanced concepts
Human research:					
Body systems Psychophysiology and behavioral sciences.	Environmental physiology Capabilities and capacities Habitability	Biomedicine and personnel selection	Bioinstrumentation monitoring	Human performance	Human capabilities and capacities (Cybernetics)
Biotechnology:					
Life support systems. Protective systems. Man-machine control.	Environmental and atmospheric control Safety Information displays Controls	Man-machine design	Ecological subsystem	Man-equipment performance	(Bionics)
Man-system:					
System analysis Human factors	Mission functional performance Reliability concept Task equipment Human engineering Maintainability Training	Man-system design	Integral ecological system	Man-systems performance	Advanced manned aerospace systems; e.g., hypersonic transportation and high thrust nuclear

TABLE 25-II.—*Biotechnology and Human Research Program—Center Participation*

	Ames	Langley	Flight	Manned spacecraft	Marshall	Lewis
Human research:						
Environmental physiology	X		X			
Psychophysiology	X		X			
Life support:						
Environmental control	X	X		X		
Protective systems:						
Safety	X	X		X		X
Man-machine:						
Displays and controls	X		X			
Man-system integration:						
Systems analysis	X	X	X		X	
Human factors	X	X	X		X	

HUMAN RESEARCH

The man, or human research, area includes the study of man and his body systems in relation to the normal and abnormal internal and external environments. (See fig. 25-1.) In this

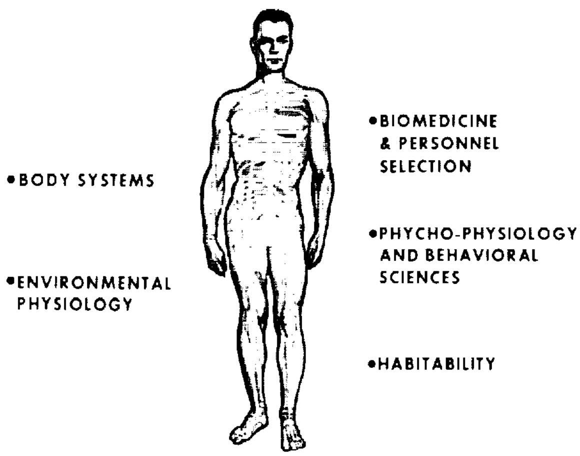

FIGURE 25-1.—Research interests of the Human Research Division.

area, we are interested in a better understanding of man to determine his performance capabilities and capacities under environmental conditions and under combined stresses, during various aerospace missions under consideration. We are also interested in being able to do research in biomedicine in order to select the appropriate personnel to fulfill the various flight and ground based task requirements. This area also includes the determination of habitability requirements, which are useful in the design of equipment and the advanced aerospace system.

At the present time, we have not obtained fundamental direct studies of the heart and circulation in order to develop and use indirect monitoring techniques for man's survival and optimal performance in space. Studies in biotelemetry are expected to identify physiological parameters to determine the physical, emotional, and psychological state of man in flight or in orbit. This is a radical approach, unbiased by conventional medical practice, but oriented toward the monitoring of man performing tasks miles out in space. These functional studies cannot be obtained through the use of conventional electrocardiographic (EKG), blood pressure, and other available methods. The absence of normal cardiovascular stimuli may not be overly serious during orbital flight but upon reentry it could lessen the circulatory system's adaptability to sudden transition from prolonged zero-g to rapidly rising and high positive g-force. Therefore, long zero-g flights in excess of 30 days and preferably in excess of several months should be performed on animals and man as soon as technologically feasible. We will continue work through contracts to Atomic Energy Commission, Department of Defense, universities, and industry. Studies on low and high magnetic fields on humans may indicate some possible physiological effects, such as disrupted biological rhythm and space-time perceptions. Pharmaceutics research, relative to therapeutics and prophylaxis and previously limited to radiation protection, will be expanded to include remedies for counteracting motion sickness and other environmental stress factors. For example, the University of Washington is studying the mechanisms by which a.c. and d.c. fields may be utilized in controlling consciousness, that is, electronarcosis. Atmospheric studies will be continued in variables such as the oxygen and nitrogen content of specific environments. It is also conceivable that the many processes of aging may be understood by the fundamental effects of O_2 toxicities. New areas of intensive investigations are the planned studies on nutritional adequacies.

BIOTECHNOLOGY

The man-machine area is intended to include all the equipment requirements needed by man to perform aerospace missions: Life support systems, protective systems, and bioengineering. (See fig. 25-2.)

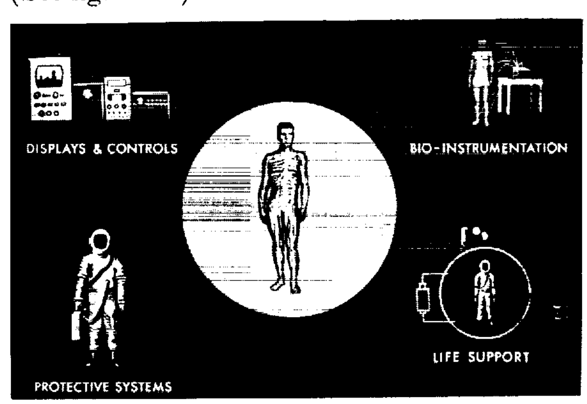

FIGURE 25-2.—Research interests of the Biotechnology Division.

Studies assigned to the area of advanced life support systems will continue to receive major emphasis in the next several years. This office plans to investigate a family of life support systems and subsystems. The Manned Spacecraft Center, Houston, has been authorized and funded to study and develop advanced life support systems just beyond the Apollo system. A contract is being negotiated by this headquarters Program Office with an aerospace firm for a completely integrated, 5-man, 30- to 60-day life support system. It includes atmospheric control (super oxide), water, food, and waste management to be demonstrated about June 1963. As part of our program, Langley Research Center recently requested proposals from a number of industrial firms for the design, fabrication, and test of a prototype 6-month life support system for 4 men. Study work in progress will determine the requirements for a 1-year life support system. This advanced system will be contracted in fiscal year 1964, depending on the progress of the other work. Biological life support concepts have been critically reviewed and a systematic approach by NASA in collaboration with other interested Government agencies will continue. As an example, Ames Research Center is monitoring a contract on a closed ecological cycle, with a photosynthetic gas exchanger at the University of Minnesota. Biofuel cells (generation of electrochemical power) are being investigated in conjunction with the Directorate of Propulsion and Power Generation. Biofuel cells as an adjunct to the life support system show more promise in the very real and complex problem of fecal and urine waste management than just long duration low power. A General Electric contract has been initiated in this area. Following the completion of our "Manned Locomotion and Protective System Study" by Bell Aerosystems Co., additional proposal requests will be made in the areas of advanced anthropometric and nonanthropometric space suits and locomotion devices in free space and on lunar and planetary surfaces. Projected milestones in this area are exemplified by the development. In other Biotechnology areas, proposals will be requested in early 1963 for a "Psycho-Physiological Monitoring System" through the Flight Research Center at Edwards. New concepts in bioinstrumentation will receive additional attention in the coming years.

MAN-SYSTEM INTEGRATION

This area includes: systems research, personnel subsystems, and simulation and test. It involves the identification of the mission requirements in order to determine the role that man will play in the systems. The principal goal is to integrate man in the overall system, and to determine man-system performance through simulation and test, both ground based and flight, prior to the design of the specific aerospace vehicle. (See fig. 25-3.)

Through fiscal year 1963, the Man-System Integration area includes systems research and analyses of the total man-machine complex. Biomedical monitoring advanced equipment is being provided for the motion flight simulators, R4D and X-14 aircraft, at the Ames Research Center, and for use in the F-100C, and a backup system is being provided for the X-15 aircraft at the Flight Research Center. This program will permit refinement of psychophysiological monitoring.

Several programs initiated in fiscal year 1963 are aimed at improved safety in aircraft. Continuation and, in several cases, expansion of effort will be required in fiscal year 1964. One such program is to set up design principles aimed at providing increased pilot's capability in affecting recovery from unusual attitudes brought about by poststall gyrations, transition from VFR to IFR flight, and lateral-directional cross coupling.

An additional group of continuing studies which began in fiscal year 1963 are aimed at understanding the involvement of the pilot in planetary or spacecraft missions. One such task involves piloted simulations and flight

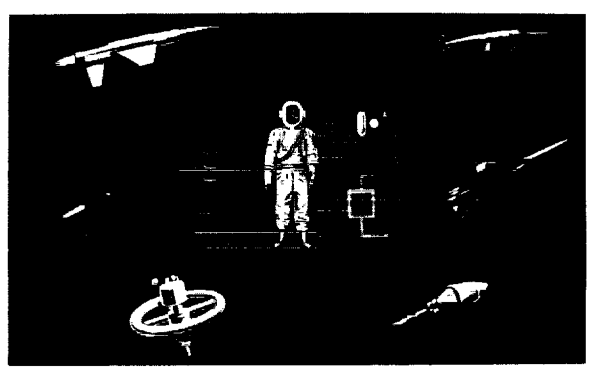

FIGURE 25-3.—Research interests of the Man-System Integration Division.

tests to determine the proper function of the human operator in a planetary landing system (atmospheric), the characteristics to be built into the vehicle and its systems for optimum performance and reliability, and the requirements for applicable research and training simulator. Another study is being made using simulation techniques to determine the role of the pilot in the rendezvous of spacecraft. A study has been initiated to obtain human design requirements for an early space laboratory and is in support of the advanced concepts studies.

The "In-Flight Maintainability Study" recently formulated by an NASA and Department of Defense working group to provide information on the performance capabilities of man in space will be ready for competitive bids in the near future. The project will be conducted through the Marshall Space Flight Center. This program involves testing of subject capabilities to perform tasks when in space suits. An additional study area to be initiated in fiscal year 1964 involves the requirements for man-rating nuclear space vehicles currently under development, or envisioned in the near future.

ADVANCED CONCEPTS

Advanced concepts include the various areas of human research, biotechnology, and man-system integration, which could lead to improvement of existing techniques or reveal the potentials of new approaches, such as system analyses, human analogs, and bionics. Studies of various supportive manned systems which appear to be beyond present-day technology, such as, high thrust, manned nuclear systems, or fusion rockets, could be utilized for future manned operations. Present studies on systems analyses includes a study of advanced aeronautical (e.g., V/STOL) systems as well as man-operated ground support equipment.

In the last few years, the great industrial aerospace complex has acquired an impressive interdisciplinary capability in bioastronautics. Industry presently conducts over 70 percent of the biotechnology and human research contract work, and is expected to continue at this high level in the years to come. Industry, universities, and other Government agencies are being encouraged to discuss and propose advanced concepts and research on one area or a combination of areas discussed herein with personnel in the Biotechnology and Human Research Headquarters Program Office.

26 Space Nuclear Systems

HAROLD B. FINGER
Manager, AEC–NASA Space Nuclear Propulsion Office and
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The early and practical utilization of nuclear energy in space is a major goal of NASA's advanced propulsion and power generation program. We are convinced that nuclear energy is required for propulsion and power if we are to accomplish our goal of thorough exploration of space and application of space technology for the benefit of mankind. To this end, we have adopted the program philosophy of working concurrently on development and on advanced research and technology. Essentially, we utilize the closest available technology in order to provide early hardware developments which are aimed at determining the feasibility of systems and at evaluating the flight problems that we will encounter when we start operating systems in the flight environment. These early developments are so designed that they will provide a growth capability for early application in operational missions. While we proceed with this early development program, we consider that a major and essential part of the program is a parallel and continuing advanced research and technology effort. This effort will provide the technology in support of the early development program and of advanced high power systems, and it will also evaluate the feasibility of new ideas that are proposed.

Our program is composed of two major parts, nuclear rocket systems and nuclear electric power and propulsion systems. A large portion of these programs is a combined effort between AEC and NASA. Responsibility for providing the required reactor research and development rests with the Atomic Energy Commission. NASA assumes responsibility for the nonnuclear component research and development programs as well as for the integration and application of the overall systems. The management organization is shown in the figure 26–1 and consists of two main organizational segments, the Joint AEC–NASA Space Nuclear Propulsion Office located at AEC Headquarters, and the NASA Office of Nuclear Systems at NASA Heaquarters. This organization insures a single channel of coordination from NASA to the AEC on all developments of nuclear systems for space propulsion and power.

The development of nuclear rocket propulsion systems is under the management of the Space Nuclear Propulsion Office. The SNPO reports to both the AEC and NASA, is staffed by both agencies, and is considered a field office in both agencies, operating with its own budget, accounting functions, technical direction, procurement authority, and so forth. The detailed day-to-day technical direction and contract administration functions are handled through the three extensions of SNPO in Albuquerque, Cleveland, and Nevada. Various phases of the work in the nuclear rocket propulsion program are conducted by Los Alamos Scientific Laboratory, Argonne National Laboratory, Aerojet-General, Westinghouse, Lewis Research Center, and other Government and industrial groups under SNPO management and direction.

The Office of Nuclear Systems operates dif-

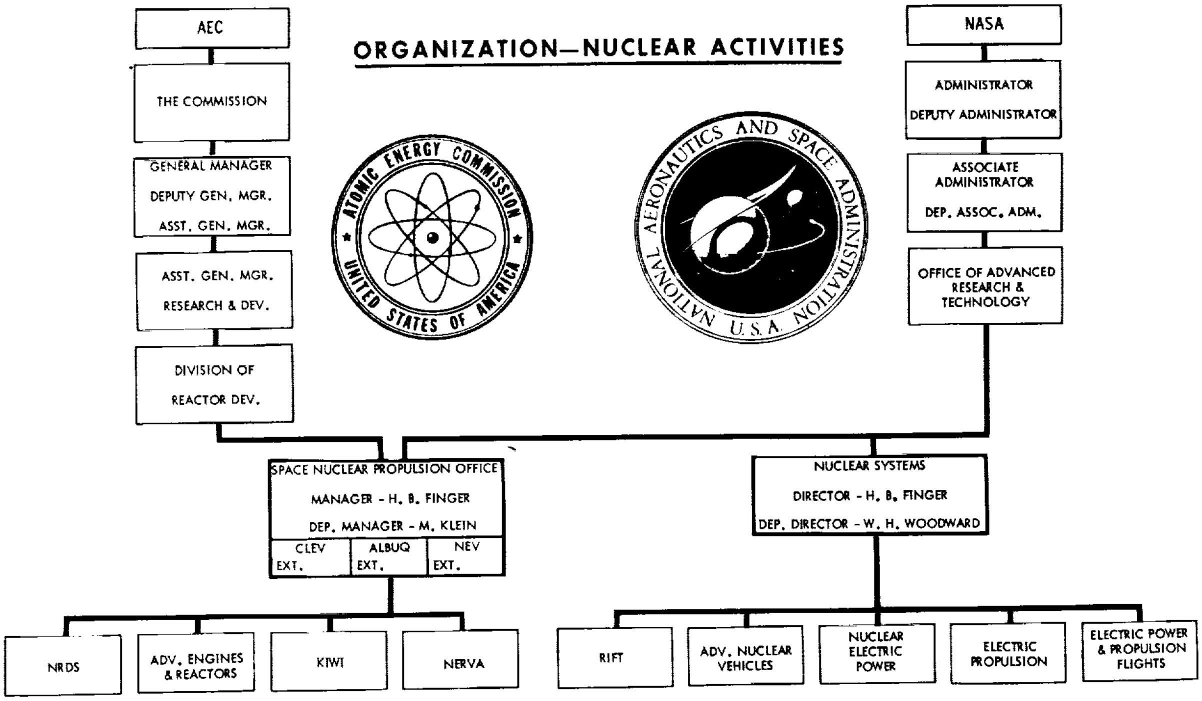

FIGURE 26-1.—AEC-NASA management organization for the nuclear program.

ferently from the SNPO in that it is exclusively an NASA Headquarters staff organization. It is responsible for overall program planning and review, establishment of program objectives, preparation of budgets, and the review of technical decisions, configurations, contracts and policies established by the field center responsible for program execution. Responsibility for detailed technical direction, contract administration, procurement, and so forth, is carried by the NASA research and space flight centers. For example, the Marshall Space Flight Center directs the Rift development and the Lewis Research Center directs almost all of the work on nuclear electric power and electric propulsion. The work is conducted partially within the centers but primarily by industrial organizations.

NUCLEAR ROCKETS

The nuclear rocket program is composed of several major hardware elements with the necessary facility effort and a strong advanced research and technology program. The relationship of three of these elements, Kiwi, Nerva, and Rift, is illustrated in the figure 26-2. The reactor technology obtained from the Kiwi project will be used in the development of a flight propulsion system in the Nerva project. The Nerva propulsion system will be flight tested in the Rift stage. The Rift stage will be designed to fit the Saturn V launch vehicle in such a way that with continued development, an early operational capability will be realized. Some feeling for the size of the Rift stage can be obtained by comparing it with the man shown in the figure. The other portions of this figure are not drawn to the same scale.

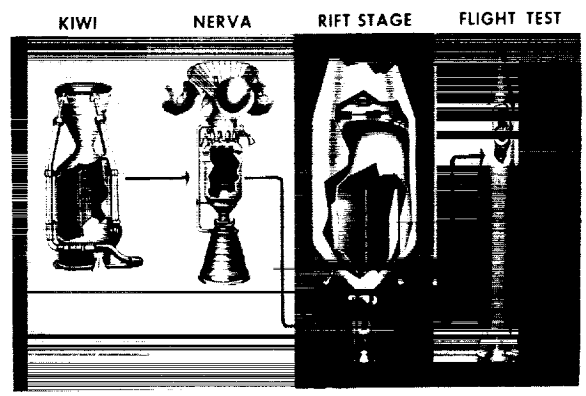

FIGURE 26-2.—Major steps in the nuclear rocket development program.

Kiwi Project

Progress made in the Kiwi and Nerva reactor portion of the project sets the pace for the Nerva engine and Rift vehicle projects. Three Kiwi–A research reactor tests were run in 1959 and 1960, followed by three Kiwi–B experiments in 1961 and 1962. In the Kiwi–B series of reactors, the Los Alamos Scientific Laboratory established several designs which represented different approaches to the solution of problems associated with the use of brittle graphite materials in the environment of a nuclear rocket reactor. In the conduct of this phase of the program, Los Alamos has worked with ACF Industries, Inc.; Air Products and Chemicals, Inc.; Edgerton, Germeshausen and Grier, Inc.; Bendix; Rocketdyne; and other groups.

The first of the Kiwi–B designs, the Kiwi–B1–A reactor, was tested with gaseous hydrogen coolant flow in December 1961. A similar reactor, Kiwi–B1–B, was then tested with liquid hydrogen flow, as is required in a flight rocket engine, in September 1962. A photograph of that reactor at the test cell is shown in figure 26–3. This is the general configuration of the test setup of all reactors run to date. They have been fired with the exhaust jet pointing upward to simplify the facility installation. The nozzle in this test was cooled regeneratively with liquid hydrogen. The results of this test indicated that the reactor could be started stably with liquid hydrogen. However, in this Kiwi–B1–B design, damage occurred in the reactor core similar to damage that had occurred in certain of the Kiwi–A tests. The fact

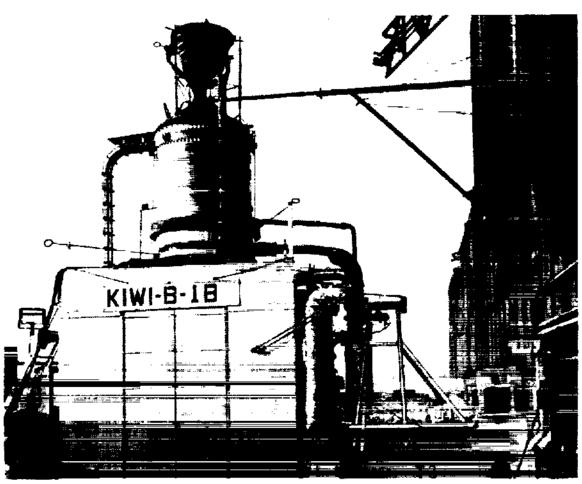

FIGURE 26–3.—Kiwi–B–1B reactor at the test cell.

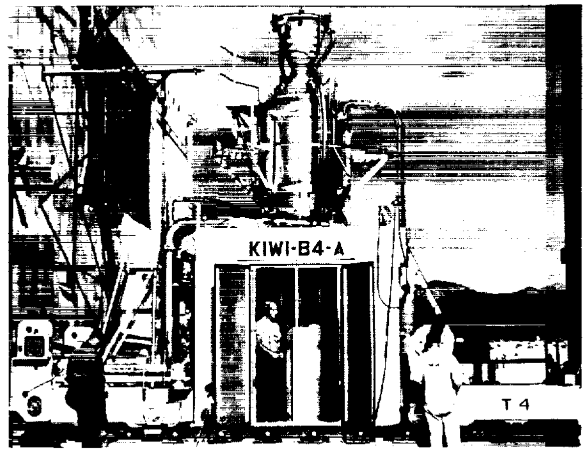

FIGURE 26–4.—Kiwi–B4–A reactor at the test cell.

that this damage has not been explained through extensive laboratory tests and analyses has made us discard the Kiwi–B1 design, for the present, as a candidate for the Nerva engine.

The most recent reactor test, the Kiwi–B4–A, was conducted by Los Alamos in November 1962. A photograph of that reactor is shown in figure 26–4. This reactor is, externally, very similar to the Kiwi–B1 reactor. However, the core design is substantially different. Almost as soon as the test of the Kiwi–B4–A reactor was started, flashes of light were noted in the exhaust jet. The test was continued until the flashes of light occurred so frequently that it was determined more could be learned by shutting down than by continuing. After disassembly of the reactor, it was found that there was extensive damage, probably due to vibrations that originated in the reactor. Work is now actively underway by Los Alamos and Westinghouse to modify the mechanical design so as to reduce the possibility of a recurrence of such vibrations to a minimum. Before the next reactor full power tests are run, component, subassembly, and full-scale mechanical and cold-flow testing will be conducted to evaluate the failure mode hypothesis and to check the suitability of redesigns.

In the near future, our major emphasis will continue to be on the reactor. We are, however, proceeding with nonnuclear component work in both the engine and the flight test stage programs aimed at evaluating the critical, long lead time, design and operating problems. While we will be pursuing work in these critical nonnuclear areas, the procurement of large numbers of flight components aimed at developing those components to high reliability will not be conducted until successful reactor operation is achieved. The President has indicated that when successful reactor operation is achieved, additional funds may be forthcoming for this heavy hardware effort.

Nerva Project

The next element of our program is the Nerva development. This development is being conducted by Aerojet General Corp., with Westinghouse Electric Co. as the principal subcontractor for reactor development. In addition, Bendix and American Machine and Foundry are subcontractors to Aerojet. A full-scale mockup of the Nerva engine is shown in figure 26–5. The engine stands 22 feet high. Shown in the figure are the reactor, the regeneratively cooled nozzle, the control drum actuators, and the thrust structure at the top of the engine. The turbopump, the tank shut-off valve, and gimbal bearing about which the entire engine may be swiveled for thrust vector control are mounted within the upper thrust structure section. The large spheres at the top of the engine are pressurized gas bottles used as a drive source for the pneumatic actuators in the system.

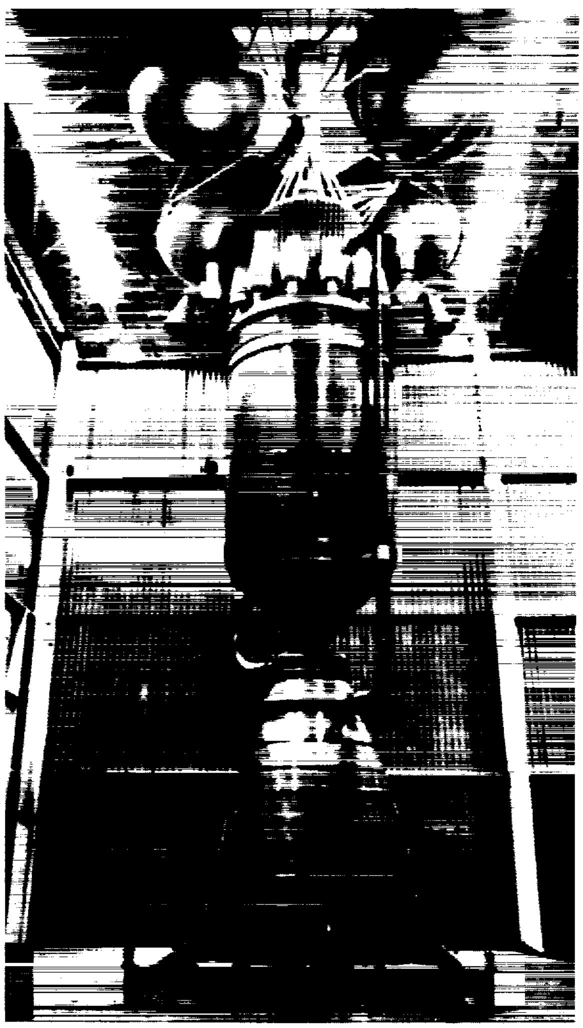

FIGURE 26–5.—A full-scale mockup, 22 feet high, of the Nerva engine.

Rift Project

As mentioned previously, the primary purpose of the Rift project is to flight test the Nerva propulsion system. Its design will also consider its eventual development to operational status as a third stage on the Saturn V vehicle. This stage is being developed by the Lockheed Missiles & Space Co.

The Rift stage will be 33 feet in diameter, the same diameter as the Saturn V vehicle. From the exit of the Nerva jet nozzle to the top of the stage, it will stand approximately 86 feet tall. With the required flight nose cone added, the total height of the stage will be in excess of 130 feet. (See fig. 26–6.)

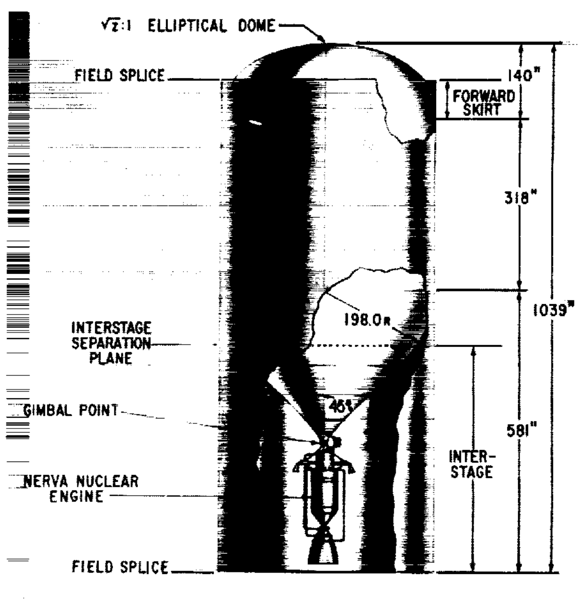

FIGURE 26–6.—Rift stage of the Saturn V vehicle. This stage is 396 inches in diameter, 1,039 inches high, and has a total weight of 200,000 pounds of which 156,000 pounds is propellant weight.

Several unique problem areas are associated with the development of this Rift stage. It will require the largest flight tank ever constructed for liquid hydrogen. The combined effects of low temperatures, resulting from the use of liquid hydrogen, and the nuclear radiation generated by the reactor in the Nerva engine on the materials, structures, insulations, propellants, and so forth, represent problem areas where research is now beginning. The nuclear flight safety requirements will require the development of new techniques for checkout, launch operations, and destruct systems in addition to those that are already provided for range and flight safety in nonnuclear applications. The combination of the comparatively heavy gimbaled nuclear engine and the large, but relatively lightweight, tank of liquid hydrogen present unique aerodynamic and structural loadings and thrust vector requirements. Finally, the requirements for engine restart and reactor cooldown after power cycles will impose additional factors that must be considered in design of the tank pressurization, venting, and particularly the guidance and control. Four flight tests are planned utilizing the Saturn V launch complex at the Atlantic Missile Range. These flights will be conducted with the Rift stage mounted on top of the Saturn V first stage using water ballast to obtain the proper acceleration conditions.

NUCLEAR ROCKET DEVELOPMENT STATION

The Nuclear Rocket Development Station (NRDS) is an area located approximately 90 miles northwest of Las Vegas, Nev., in which facilities are being provided for all power testing of reactors, engines, and stages required in the nuclear rocket program. The station is managed by the Nevada Extension of the Space Nuclear Propulsion Office for the AEC and NASA. The large distance between the Nuclear Rocket Development Station and Las Vegas has made it necessary for the AEC, with NASA participation, to study comprehensively the means by which a community could be established near the test facilities so that recruitment and retention of the large number of high caliber people required in the program can be encouraged.

The general layout of the test facilities that are being established at the NRDS is shown in figure 26–7. These facilities can be divided

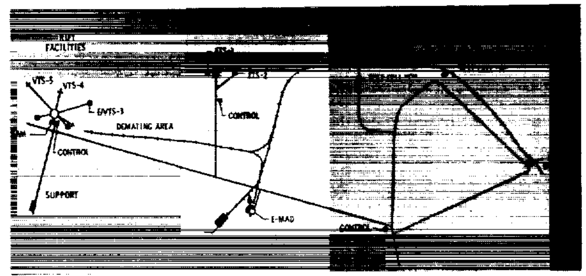

FIGURE 26–7.—Test facilities at the Nuclear Rocket Development Station.

into reactor facilities, Nerva engine facilities, and Rift stage facilities. Some of the reactor facilities have been in operation for several years and have provided the capability for assembling, disassembling, and testing the Kiwi reactors described previously. An additional reactor test cell, Test Cell C, is now nearing completion, and expansion of Test Cell A is being initiated. In addition, some of the Nerva facilities are under construction and others are under design. Engine Test Stand No. 1, formerly designated Test Cell D, is well along under construction. The second engine test stand is being designed. The building in which the Nerva engines will be assembled, maintained, and disassembled is being constructed. In addition, support facilities will be designed and built during this year and next year. None of the Rift facilities have been funded for construction as yet, although design work will proceed in a limited way on certain of these facilities. It is important to emphasize that the facilities being built at the Nuclear Rocket Development Station in Nevada provide a national development capability for nuclear rockets that will not be duplicated anywhere else. This site could, therefore, be considered as the National Nuclear Rocket Development Station.

NUCLEAR ROCKET ADVANCED RESEARCH AND TECHNOLOGY

The last major element of the nuclear rocket program is the Advanced Research and Technology program which is aimed at providing technical support for our hardware development projects and also for providing the capability to build reactors and propulsion systems having performance characteristics well beyond those now under development. The principal work areas include reactors, nozzles, controls, and instrumentation, turbopump and flow systems, system studies and mission analysis, and advanced concepts. Under the reactor area, the AEC and NASA are looking at concepts other than the graphite systems being used in Kiwi-Nerva. We are evaluating materials properties for such systems. We are working toward high specific impulse and long life systems over a wide range of power. This reactor area is the key to future advanced systems. However, much remains to be done in nozzle, pump, and control technology before we can develop reliable, high-performance systems.

NUCLEAR ELECTRIC PROPULSION AND POWER GENERATION

In addition to nuclear energy for nuclear rocket propulsion, nuclear energy for electric power and electric propulsion will be required. In the range of hundreds of kilowatts to many megawatts, the only practical source of electrical power is nuclear energy. Representative applications of such power levels include orbiting manned space platforms, manned interplanetary spacecraft, communications satellites, and unmanned planetary probes. These applications can generally be divided into the needs for on-board power for communications, life support, data acquistion, and so forth, and the power required for electric propulsion. The estimated electrical power requirement for on-board power is on the order of 30 to 60 kilowatts which is within the capability of the Snap-8 Electrical Generating System now under development by NASA and the AEC. These estimates are based on a space platform which might weigh 200,000 pounds, so the Snap-8 system will use less than 2 percent of that weight.

Another propulsion application, in the more distant future, is the manned interplanetary spacecraft. Such a vehicle would weigh a million pounds or more, might require orbital assembly, and would utilize a large electric rocket propulsion system requiring 20 to 30 megawatts of electrical power. The usefulness of electrically propelled spacecraft is critically dependent upon the weight of the nuclear electric power generation system which produces the electrical power for the electric rocket engines. A power generation system weight of 10 pounds per kilowatt or less including shielding would result in a spacecraft weight competitive with a nuclear rocket for a manned Mars mission. Low power systems such as Snap-8 will weigh in the neighborhood of 100 pounds per kilowatt.

TABLE 26–I.—*Nuclear Electric Systems; Program, Goals, and Elements*

Program	Goals	Elements
Power	10 pounds per kilowatt	Snap-8 development
	Watts to megawatts	Snap-8 flight evaluation
	Long life	Advanced research and technology
		Mecca (zero-g flight tests)
Engine	High efficiency	Engine development
	Long life	Advanced research and technology
	0.01 to 10 pound thrust.	Sert (Space Electric Rocket Tests)

Table 26–I lists the program goals and major program elements of our nuclear electric power and electric propulsion programs. Several of the goals of both the power and propulsion subprograms are similar. Maintenance-free life of years will be required. As mentioned previously, low weight is essential for propulsion systems, hence the power program goal of 10 pounds per kilowatt of electricity produced. It is important to note that for on-board power systems, such low weight is desirable but not essential because of the large vehicles now being developed. The earlier example of the relatively heavy Snap-8 system being used to power a 200,000 pound space platform is a good illustration of this point in that the power supply would still be less than 2 percent of the spacecraft weight. With regard to the electric propulsion program, high thrustor or engine efficiency is of major importance rather than engine weight, since the weight of the electric rocket engine itself is small (10 percent or less) in comparison with the electric power generation system needed to drive the rocket engine.

Electric Power Generation

The power subprogram consists of the Snap-8 Development, the Snap-8 Flight Evaluation,

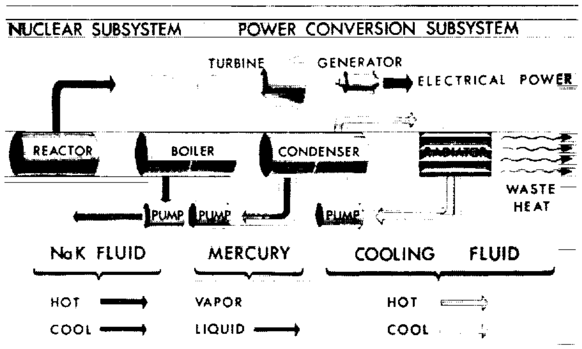

FIGURE 26-8.—Schematic drawing of the Snap-8 electrical generation system.

the Advanced Research and Technology, and the Mecca Project.

Snap-8 Development Project. The Snap-8 is a 30-kilowatt, reactor-powered, electric power generation system suitable for space flight applications. As shown in figure 26-8, it is composed of two major components, the nuclear subsystem and the power conversion subsystem. The nuclear subsystem is composed of a nuclear reactor, shielding, and the associated pumps, tubing, and working fluid necessary to transfer the heat generated in the reactor to the boiler. The working fluid, a mixture of sodium and potassium (NaK), is heated in the reactor and pumped to the boiler where its heat energy is transferred to the mercury in the boiler. It is then pumped back to the reactor and is reheated. This reactor is being developed for the AEC by Atomics International.

The heat energy transferred to the boiler causes liquid mercury in the second loop to boil. The resulting mercury vapor passes through a turbine which extracts enough energy to drive the generator. The mercury vapor is then cooled in the condenser and the resulting liquid pumped back to the boiler for reheating. The heat energy released by the mercury in the condenser is removed by a single-phase cooling fluid which is pumped to the radiator. Here, the excess heat energy is radiated to space and the cooled fluid is returned to the condenser. Not shown in the figure is a small fourth loop needed to provide cooling for the bearing lubrication system and various electrical components. In simpler terms, heat energy produced in the reactor is transferred to the turbine section where approximately 10 percent is extracted in the form of electricity. The unused heat energy is then rejected to space by the radiator.

Cycle temperatures range from 1,300° F in the reactor to 180° F in the generator. These temperatures coupled with the 10,000-hour, maintenance-free lifetime requirement are presenting difficult problems in materials selection and bearing and seal design and primarily in achievement of high reliability. The conversion system and the system integration responsibility is assigned to Aerojet-General under an NASA contract.

SNAP-8 Flight Evaluation Project. The objective of the Snap-8 Flight Evaluation Project is to evaluate the problems of starting and operating a Snap-8 electrical generating system in the space environment and to demonstrate such operation. The spacecraft is estimated to weigh as much as 10 tons including an electric propulsion system and will be launched by a Saturn IB launch vehicle. It is important to note that no major hardware commitments will be undertaken until Snap-8 Development Project progress warrants such action. Preliminary studies of spacecraft design, operational safety problems, and so forth, are planned for initiation during this fiscal year.

Advanced Research and Technology. The Advanced Research and Technology Project is aimed at acquiring the technology on which to base the development of future systems such as that shown in figure 26-9. The 2,100° F, Rankine cycle, turboelectric system on the left utilizes lithium and potassium as working fluids and a segmented radiator to minimize radiator weight. The thermionic direct conversion system on the right of the figure is a simpler system having fewer moving parts. However, it requires a maximum temperature of approximately 3,000° F. Both systems have design

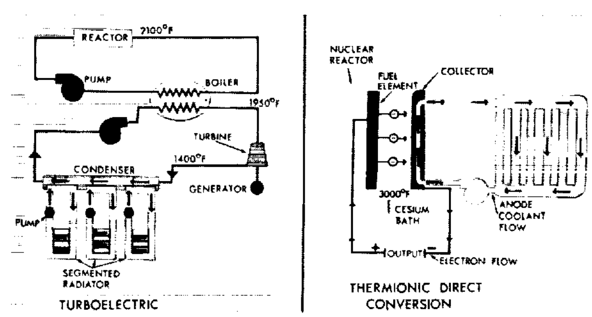

FIGURE 26-9.—Energy conversion concepts for advanced systems.

weights on the order of 10 to 20 pounds per kilowatt and are technologically far beyond current ground-based power generating devices. The uncertain micrometeoroid environment, and the lack of both basic and engineering knowledge on materials, heat transfer, flow processes, and so forth, pose serious obstacles to be overcome before hardware development of such advanced systems can be undertaken. The NASA attaches much importance to this area and, under the direction of the Lewis Research Center, is working within NASA and is conducting a vigorous program with approximately 25 industrial, research, and university contractors to provide the necessary data. This program includes such items as the experimental evaluation of viscosity, specific heats, and thermal conductivity of liquid metals and metal vapors of interest; the emissivity of radiator materials over a wide range of temperatures for space use; the boiling heat transfer coefficients of the metal working fluids at the high temperatures required; and, the compatibility of the metal working fluids with the containment materials and the components used in the system. This area of work also includes analysis and experiments on such system components as bearings, turbines, generators, pumps, and thermionic emitters.

Mecca Project. The Mecca Project is aimed at determining the effects of relatively long-time zero-gravity exposure on liquid metal boiling and condensing heat transfer. The 8 or 10 minutes of zero gravity exposure needed to establish equilibrium conditions will be obtained in freely falling vehicles at high altitudes. Experiments weighing up to 1,000 pounds will be launched by small (26,000 pounds of thrust) solid rocket-powered vehicles shown in figure 26–10. Vehicles, composed of available motors, will be launched from Wallops Island at a rate of two to three per year. The first experiments are in direct support of Snap-8 and will utilize mercury fluid and Snap-8 boiler and condenser component configurations. Data will be both telemetered to the ground and recorded on film. The camera package will be recovered using techniques already developed. The total cost of each shot is on the order of $250,000 to $300,000.

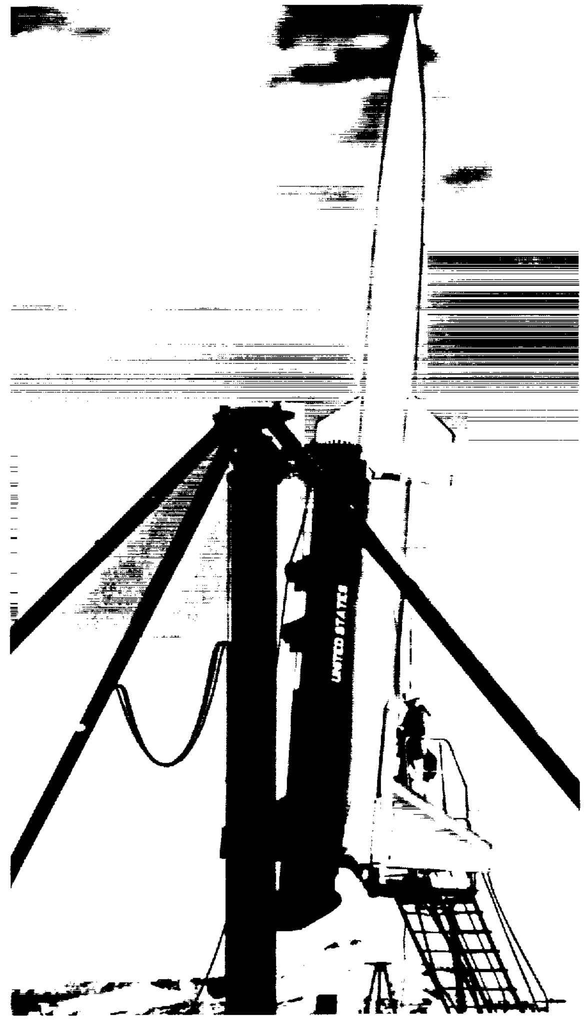

FIGURE 26–10.—Mecca vehicle on a launcher.

Electric Propulsion

The propulsion subprogram is composed of an Advanced Research and Technology Project, an Engine Development Project, and a Flight Evaluation Project called Sert.

Advanced Research and Technology Project. In the Advanced Research and Technology Project, NASA efforts are directed toward providing the basic information necessary for the development of systems. Figure 26–11 shows the three main types of electric rocket engine: the arc jet, the ion engine, and the plasma jet. The arc jet develops thrust by heating a working fluid such as hydrogen or ammonia and expanding it through a nozzle. The ion engine depends upon electrostatic forces and reactions to accelerate a working fluid such as cesium or mercury, thereby developing thrust. The plasma engine utilizes electromagnetic forces to accelerate plasmas, thereby developing thrust.

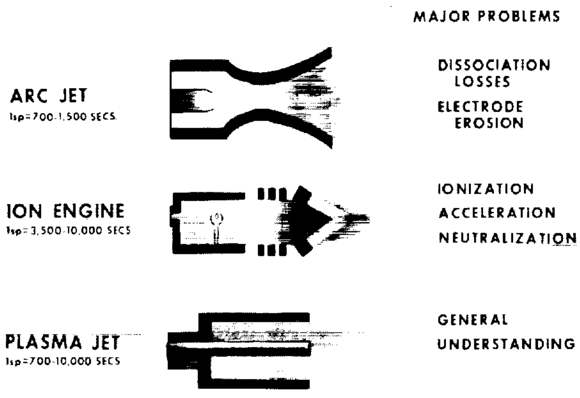

FIGURE 26-11.—The three main types of electric rocket engines.

The arc jet has a specific impulse range of 700 to 1,500 pounds of thrust per pound per second of propellant flow. The ion engine develops impulses in the 3,500 to 10,000 seconds range. The plasma jet offers the potential of covering the whole range of the other two. The engines are ranked in order of developmental status. In other words, the arc engine is closest to being ready for application.

The major problems remaining to be solved in the arc jet engine pertain to dissociation losses, which materially affect engine efficiency, and electrode erosion which has a primary effect on engine life. Typical efficiencies obtained to date range from 40 to 50 percent, while endurances of hundreds of hours have been demonstrated in ground facilities.

The state-of-the-art for ion engines, while not as advanced as far as arc jets, is sufficiently well along for us to plan flight tests to evaluate current solutions for such problems as beam neutralization, and to determine the effects of long term exposure to the space environment. These flight investigations will be discussed in more detail under the Sert Project. The other two problem areas, propellant ionization and acceleration, are under vigorous investigation by industry and the Lewis Research Center.

The plasma jet technology program is really just beginning. As indicated previously, the plasma jets offer the potential of good performance over a broad range of specific impulse. However, a good understanding of each of the many engine concepts is need before we can concentrate our efforts on one or two main approaches.

Although not shown in this figure, another advanced research and technology area that has

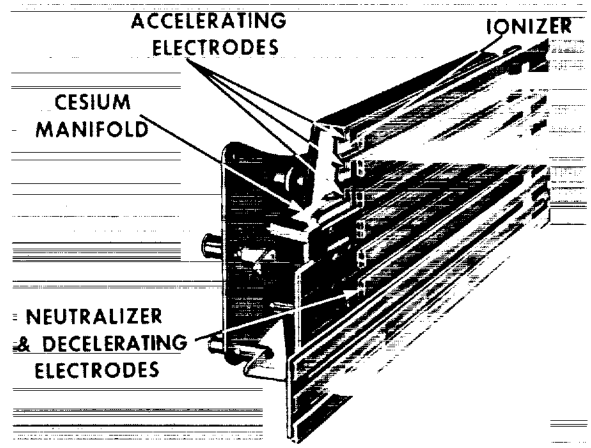

FIGURE 26-12.—The 3-kilowatt ion engine module.

been deferred in favor of work on thrustors is the power conditioning and control system. A program in these areas has been initiated this year and will be increased in 1964. Approximately 26 industrial and university contractors are involved in the various portions of this project.

Engine Development Project. The Engine Development Project consists of a number of development contracts for arc jet and ion engines aimed at providing hardware for ground and flight test purposes. Hopefully, the engines developed as a part of this project will be suitable for early applications. An example of this philosophy is the 3-kilowatt ion engine module, under development by the Hughes Aircraft Co., and the concept of clustering the basic 3-kilowatt unit into megawatt-size systems.

Figure 26-12 shows the basic engine module. It is a strip or rectangular engine rather than the circular or ring engine discussed in prior years. Its dimensions are approximately 3 by

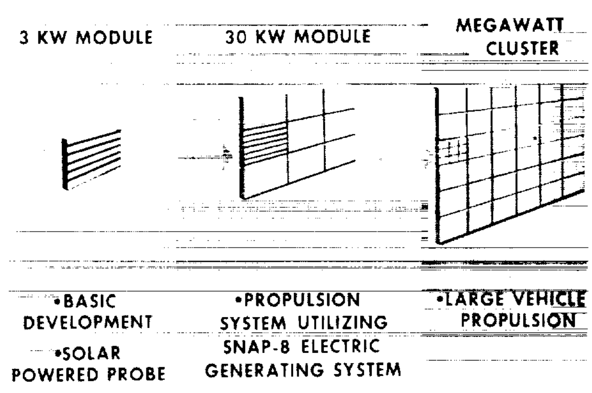

FIGURE 26-13.—Clustering concept in electric engine development.

6 inches. Figure 26–13 illustrates the clustering concept. The power levels have been selected so that each development would be suitable for the potential applications listed. On the left is the basic 3-kilowatt module from the preceding figure. This unit is used for basic research and development and is of a size suitable for solar-powered systems. The middle sketch shows a 30-kilowatt engine composed of nine clusters of the basic module. This engine would measure approximately 3 by 4 feet and is of a size for use with the Snap-8 electrical generating system described previously. The right-hand sketch illustrates our ultimate goal of a megawatt-class cluster of 30-kilowatt modules. This engine system would measure 18 by 24 feet and would be utilized to propel a large interplanetary vehicle of the type mentioned previously. Other engine developments are being conducted by Avco, General Electric, Electro-Optical Systems, and Plasmadyne.

Sert Project (Space Electric Rocket Test). The Sert Project is composed of a series of electric rocket engine tests that, in general, cannot be performed meaningfully in ground facilities alone. By comparing flight test results with data obtained in ground facilities, we will determine the limitations and accuracy of our ground tests. Because we can never expect to simulate the space environment completely, flight tests such as these are also necessary to prove or qualify specific engine developments for future mission applications. The need for flight tests is established by the Advanced Research and Technology and Engine Development Projects. Flight test engines and components for the Sert Project are furnished by the Engine Development Project.

The first Sert flight will consist of an ion beam neutralization experiment. A 350-pound, spin-stabilized capsule, built by RCA, will be launched from Wallops Island, Va., by Scout launch vehicle on the trajectory shown in figure 26–14. This trajectory will give up to 55

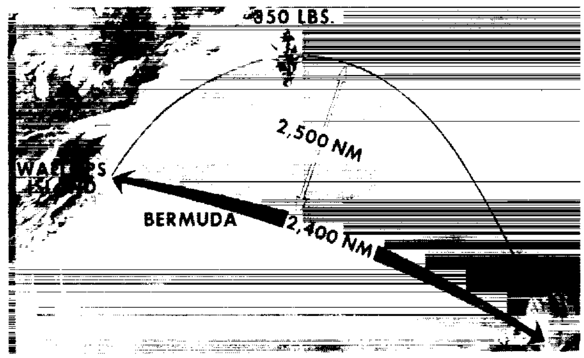

FIGURE 26–14.—First Space Electric Rocket Test (Sert) flight.

minutes of free fall above the earth's atmosphere. During this time, two ion engines will be operated in such a manner as to change the capsule spin rate. The amount of change in spin rate will be a measure of the thrust developed, which in turn is a measure of the degree of neutralization achieved. Succeeding Sert flights will involve orbital trajectories as well as the ballistic type shown here.

In summary, our major goal is the early and practical utilization of nuclear energy in space. We are convinced a substantial effort is justified by the potential performance advantages of these systems for difficult space missions. To this end, NASA and the AEC are conducting substantial joint programs.

27 Research Facilities

BOYD C. MYERS, II

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The objectives, size, and technical scope of the NASA general Advanced Research and Technology Program have been discussed in preceding papers. These papers have described the direction of our research goals and have included contract research programs with universities, with nonprofit institutions, and with industrial research organizations, as well as our in-house research programs. This paper relates the general nature of new NASA research facilities that have been added to our capability since July 1960, date of the last NASA-Industry Conference. These facilities are the basic tools used in research to obtain experimental data over a wide range of conditions to permit the rational design of future flight vehicles.

These facilities provide the means to do systematic research to identify problems, to explore the fundamental nature of these problems, and to provide new techniques applicable to their solutions. The cost, complexity, and reliability attendant with advanced aeronautical and space vehicle systems dictate that solutions which are applicable to future missions must be provided as early as possible in the vehicle development cycle.

These facilities, along with the facilities of industry, universities, other private organizations, and other Government agencies provide this country with a national asset that is designed to achieve and maintain preeminence in aeronautics and space.

CATEGORIES OF FACILITIES

Various categories of research facilities that either have been built, are under construction, or are planned for fiscal years 1961 through 1964 are as follows:

- Materials and Structures
- Space Environmental Chambers and Apparatus
- Guidance and Control Simulators and Equipment
- Fluid Flow and Plasmadynamics
- Space Power and Energy Conversion
- Life Sciences
- Nuclear Rockets
- Electronics and Telemetry

Research facilities provided for OART programs are usually quite versatile. For example, at the Lewis Research Center, the Altitude Wind Tunnel is in its third useful life. It was designed and put into operation in 1943 for research on reciprocating engines for aircraft. Within a year's time, it was converted and used almost entirely for investigating the problems of turbojet engines. Starting in fiscal year 1961, it was partly modified to provide a space chamber for research on problems of space propulsion. Additional portions are to be converted to space chamber use in the 1964 fiscal year program, and the name has now been changed to Space Power Chambers.

Research facilities in the OART program are frequently difficult to categorize by one discreet field or discipline. For example, aeronautics and chemical rocket facilities do not

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show as separate categories; however, research in these fields is conducted in the facilities listed under Materials and Structures, Guidance and Control Simulators and Equipment, and Space Power and Energy Conversion. This applies also to some other research areas.

In the discussions of the facilities under each category, it should be kept in mind that as the result of engineering effort over a 4-year period, it has become possible to improve the simulation of the problems of space in ground-based laboratories. It will be noted that the programs start in fiscal year 1961. The fiscal year, however, starts 6 months ahead of the calendar year, and the preliminary planning for the facilities starts approximately 1½ years ahead of the beginning of the fiscal year. Consequently, the facilities that are shown for fiscal year 1961 were planned initially approximately 2 years prior to the beginning of the 1961 calendar year, or 1959, the first full calendar year of operation of NASA as the Nation's space agency.

Space environment chambers are to space what wind tunnels are to aeronautics.

The categories are thus somewhat different than the program areas represented by other categories. It will be apparent, however, that each of the programs is being provided with new and modernized facilities.

Materials and Structures

The category of facilities shown in table 27–I includes bell jars to 7- or 8-cubic-foot vacuum chambers operating at a pressure of 10^{-8} mm Hg. The small facilities are required for long time tests of materials under hard vacuum conditions, up to a year or more where materials may change characteristics. Some of these changes are due to out gassing and loss of surface films as a result of exposure to hard vacuums in combination with solar radiation and impact with micrometeoroid particles.

This category of facilities includes particle accelerators for simulating micrometeoroid impact and radiation sources, both of the electromagnetic radiation type reproducing the solar spectrum and high energy particle radiation. The facilities mentioned are aimed at improving simulation of the problems of materials and structures in space.

Some of the most severe stresses occur during the launch operation phase. For this range of conditions, a high intensity noise generator operating at frequencies for 0 to 200 cycles per second is provided. Heavy backstops on which to mount launch vehicles and a wide variety of shakers are provided to simulate the launch phase. Adequate instrumentation is a necessary part of each such facility.

TABLE 27–I.—*Materials and Structures Facilities*

Name	Location	Fiscal year
Basic Materials Laboratory	Lewis	1961
Low Frequency Environmental Noise Facility	Langley	1962
High Vacuum Space Structures Facility	Langley	1962
Environmental Research Facilities for Spacecraft Components and Materials	Langley	1963
Particle Accelerator for Micrometeoroid Impact	Langley	1963
Space Radiation Effects Laboratory	Langley	1963
High Temperature Loads Calibration Facility	Flight	1964
Structural Dynamics Laboratory	Ames	1964
Fatigue Research Laboratory	Langley	1964
Space Environment Research Facility	Ames	1964

At the Ames Research Center, the Space Environmental Research Facility will provide for research on materials in vacuum chambers 5 feet in diameter at pressures down to 10^{-10} mm Hg as well as a bell jar to operate down to 10^{-15} mm Hg. In addition, materials will be subjected to particle and micrometeoroid impact.

In addition to the concern for the properties of structural materials and structural specimens under cold space conditions, facilities are provided for research on materials for use at high temperatures. Turboelectric power generating equipment is expected to operate at temperatures of 2,000° F; consequently we have provided equipment for studies in powder metallurgy and the welding of materials such as columbium, titanium, and stainless steel. Fabrication and joining of articles made from such materials are an essential part of the high-temperature liquid metal power generating technology.

Space Environmental Chambers and Apparatus

In the preceding discussion, reference was made to numerous small- to medium-size vacuum chambers used for long-term tests on materials and components of space vehicles and propulsion and power generating devices. The category given in table 27–II includes the large space environmental chambers which are quite versatile in the type of problems that may be studied. These chambers, both under construction and in the budget stage, have inside diameters from approximately 8 feet to 75 feet at heights of 120 feet and are designed to operate at vacuums of 10^{-8} mm Hg. Each of these large chambers is mainly for application to a particular area of research. The Dynamic Research Laboratory at Langley includes a cylinder 60 feet high by 60 feet in diameter in the base of which is located a centrifuge. The cylinder has a man-rated air lock, and is to operate at 1 mm Hg. Another part of this same facility is a 60-foot-diameter vacuum sphere (0.2 mm Hg) containing an air bearing, solar simulator, and a port in the outside wall of the chamber to permit star tracking by a payload mounted on the air bearing. The building part of this facility includes a high bay and a backstop sized to accommodate a Scout vehicle which is about 65 feet long. The facility can thus provide for research on structures and materials problems, guidance and navigation problems, and dynamic response of vehicle structures during the launch phase.

TABLE 27–II.—*Space Environmental Chambers and Apparatus*

Name	Location	Fiscal year
Dynamics Research Laboratory	Langley	1961
Modification of Space Environment Tank	Lewis	1962
Space Propulsion Facility	Lewis	1963
Spacecraft Propulsion Research Facility and Addition	Lewis	1963, 1964
Alteration of Space Power Chambers	Lewis	1964
Zero Gravity Facility	Lewis	1964
Satellite Attitude Control Test Facility	Ames	1964

In the Lewis 1962 program, an existing space environmental tank was modified to provide for longer time exposure to space vacuum and temperatures by providing additional cryogenic cooling capacity. In the fiscal year 1963 program at Lewis, a Space Propulsion Facility was provided which will permit the operation of nuclear reactors in a simulated space environment. This facility has an aluminum inner vertical vacuum chamber 75 feet in diameter and 120 feet to the interior of the dome. Space propulsion devices including those requiring nuclear radiation shielding can be operated in this facility.

The Spacecraft Propulsion Research Facility, also at Lewis, provides for altitude starts of rocket engines at conditions equivalent to 100,000 feet. In fiscal year 1964 it is proposed that this facility acquire the capabilities of simulating space-soak prior to startup to insure reliability of rocket restart on a long mission.

The former altitude wind tunnel at Lewis, now called the Space Power Chambers, is to be modified further by converting one whole end to a vacuum chamber 40 feet in diameter and approximately 100 feet long. This chamber will be exhausted to a pressure of 10^{-6} mm Hg and will be used for research on propulsion systems of space vehicles.

The Zero Gravity Facility simulates, during an upward projection and free-fall period, 10 seconds of zero-gravity conditions. It will operate in a vertical shaft 20 feet in diameter which is exhausted to a vacuum of 10^{-2} mm Hg.

At Ames, the Satellite Attitude Control Facilities will have a vacuum chamber with an inside diameter of 140 inches and will be equipped with a gas bearing and simulated references such as the sun, earth, and stars.

Guidance and Control Simulators and Equipment

The guidance and control simulators, table 27–III are primarily intended for manned flight, both in the earth's atmosphere, in space, and for landings on lunar and planetary surfaces. In this equipment, the pilot sits in an enclosure much like an aircraft cockpit and is subjected to motions and visual cues such as would be expected in actual flights.

In fiscal year 1961, Ames initiated the construction of a 30-foot-arm centrifuge with gimbaled cab providing five degrees of freedom. This has been in operation since December 1961. In fiscal year 1962, Ames started construction of

TABLE 27–III.—*Guidance and Control Simulators and Equipment*

Name	Location	Fiscal year
Centrifuge equipment	Ames	1961
All-Axes Motion Generator	Ames	1962
Lunar Landing Facility	Langley	1962
Space Flight Guidance Research Facility	Ames	1963
Visual Flight Simulator	Flight	1963
Stabilization and Control Equipment Laboratory	Langley	1963

an All-Axes Motion Generator which has six degrees of freedom. In this the pilot can rotate or move in translation in any direction.

Also in fiscal year 1962, Langley started construction of a Lunar Landing Facility. This facility has a simulated lunar landing vehicle suspended from an overhead gantry so that it is counterbalanced to lunar gravity or one-sixth of earth's gravity. With this facility, vehicle lunar landings can be simulated under safe conditions. In the fiscal year 1963 program at Ames, the Space Flight Guidance Research Facility was started which basically is a centrifuge with a 50-foot arm in which pilot performance and life support systems relative to lunar or planetary missions can be simulated. (See fig. 27–1.) A stress history on the pilot can be

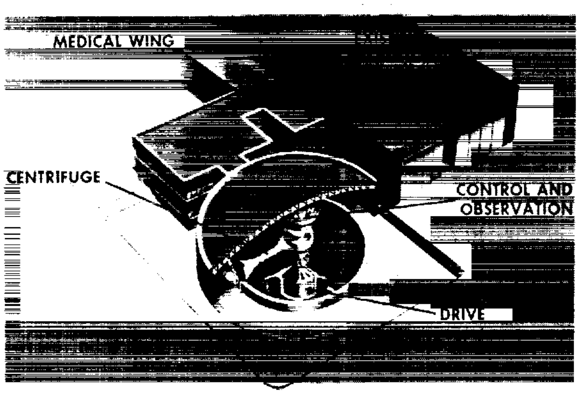

FIGURE 27–1.—Space Flight Guidance Research Facility, Ames Research Center.

built up through operation over the same length of time that would be required for a lunar or planetary flight, using the same life support systems as in space.

In the fiscal year 1963 program for the Flight Research Center, a Flight Simulator was started which is to provide visual cues to a pilot in what was previously a hooded-cockpit type of simulator. The pilot can fly an aircraft mission with reference to his exterior surroundings as well as the instrument indication. The Stabilization and Control Equipment Laboratory in the 1963 program at Langley is to provide for research on advanced guidance and navigation components. This facility will contain optical equipment and stable platforms necessary for determining the accuracy, reliability, and response of a variety of control and guidance equipment used on space flights.

Fluid Flow and Plasmadynamics

The fluid flow and plasmadynamics facilities, table 27–IV, represent the extension of capabilities of wind tunnels which do such yeomen services in aeronautics. Starting in fiscal year 1961, these facilities represent a steadily increasing capability to simulate at a useful scale the reentry flow conditions first from an earth orbit, then return from a lunar mission, and approaching return from an interplanetary mission.

The Hypersonic Aerothermal Dynamic Facility at Langley is really four wind tunnels—one with air at very high pressures and a 4,500° R stagnation temperature, a second with a 15,000° R stagnation temperature with air at moderate

TABLE 27–IV.—*Fluid Flow and Plasmadynamics Facilities*

Name	Location	Fiscal year
Hypersonic Aerothermal Dynamics Facility	Langley	1961
Hypervelocity Free Flight Facility	Ames	1962
Equipment for Magneto-plasmadynamics Research	Langley	1962
Radiative Heat System for Mass Transfer Facility	Ames	1963
Mach 50 Helium Tunnel	Ames	1963
Additional power supply and improved arc chamber for 10 Megawatt Arc Tunnel	Langley	1963
Hot Gas Radiation Research Facility	Langley	1964

pressure, and two helium wind tunnels to simulate Mach numbers of 10 and 20, respectively. During reentry processes into the earth's atmosphere, the flow around the body becomes so heated that the air is dissociated and ionized into a plasma. By creating the plasma conditions directly, such as in the Langley project, Equipment for Magnetoplasmadynamics Research, specific problems can be studied, such as attenuation of radio signals through the plasma sheath. Larger scale equipment permits more realistic scaling of the problem.

Starting in fiscal year 1963 at the Ames Research Center, an additional method of simulating the heat of a body reentering the earth's atmosphere was initiated by applying the heat from arc heaters through windows in the wall of a wind tunnel which already had streams heated to very high temperatures. By this means much more realistic simulation of the actual heat of reentry can be provided. Also in 1963 at Ames, a Mach 50 Helium Tunnel is being provided which will simulate the flow field of a planetary reentry body without providing extreme heat. The technique of providing the extreme heat condition of reentry into the earth's atmosphere is dependent upon the use of special arc heaters.

The project for the power supply and arc chamber for the Langley 10 Megawatt Arc Tunnel will provide the latest technical know-how in a hypersonic flow facility using air.

In the Hot Gas Radiation Research Facility, by using electrically driven shock tubes, Langley plans to simulate planetary reentry conditions. This facility will provide radiative heat at levels greater than those typical of Apollo entries into the earth's atmosphere.

Space Power and Energy Conversion

The facilities for space power and energy conversion, table 27–V, are intended to meet the needs of basic research of electric power in space, from solar, nuclear, or chemical energy sources. In fiscal year 1961, the Energy Conversion Laboratory was started and is now in operation. The research in this facility covers basic phenomena such as conduction through gas, means of extracting power from solar radiation sources and the study of rectifiers, transformers, and other components in simulated space environments. In effect, it provides means for studying electrical energy conversion components which are specially designed for space application. Space power research facilities were provided also in 1961 at Lewis for the study of space radiators in a vacuum environment.

TABLE 27–V.—*Space Power and Energy Conversion Facilities*

Name	Location	Fiscal year
Energy Conversion Laboratory	Lewis	1961
Space Power Research Facilities	Lewis	1961
Propellant Flow Facility	Lewis	1964
Electric Power Equipment Test Facility	Lewis	1964
Propulsion Component Evaluation Facility	Lewis	1964
Snap-8 Assembly and Spacecraft Checkout Building	Lewis	1964

In fiscal year 1964, facilities are proposed for Lewis to study the flow problems of cryogenic propellants which may be used for either propulsion or space power. The Electric Power Equipment Test Facilities proposed for 1964 will provide for further work on electrical components of space power systems using an existing capability of 15,000-horsepower variable frequency power supply. The Propulsion Component Evaluation Facility proposed for Lewis is being provided for research on the reliability of elements of space propulsion devices. A series of bell-type chambers in sizes up to about 100 cubic feet in volume and at vacuums down to 10^{-9} mm Hg are to be provided.

In addition, a facility for housing preflight testing and integration equipment for the Snap-8 flight test vehicle is proposed for fiscal year 1964. This facility will permit the assembly of the Snap vehicle and bring the nuclear reactor up to criticality prior to its installation in the space propulsion research facility or packaging for shipment to Cape Canaveral for flight testing. This facility will have an evacuated biologically shielded containment vessel to minimize hazards in the event of a malfunction. It will be provided with liquid metal systems, a white room, space-soak equipment, shops, and health physics equipment.

Life Sciences Facility

The OART projects most specifically related to the Life Science program are indicated in table 27–VI. Other facilities such as the Ames Space Flight Guidance and Control Research Facility will be located in proximity to the Life Science Facility for studying the related problems of stress history and astronaut performance.

TABLE 27–VI.—*Life Sciences Facilities*

Name	Location	Fiscal year
Modifications to Flight Operations Laboratory	Ames	1962
Life Sciences Research Facility	Ames	1964

The project modifications to Flight Operations Laboratory, was an initial effort by the Ames Research Center to provide space for the Life Science Research group. In this facility, offices were built into an existing aircraft hangar.

In fiscal year 1964, it is proposed that the Ames Research Center will build a Life Sciences Research Facility. This will be a wet laboratory devoted to research in biomedicine, exobiology, and biotechnology. In the facility, some 106,000 square feet of laboratory space will be provided which will serve as an adequate center for facilities of this type scattered at various locations at the Ames Research Center, and to provide needed additional space for the increasing NASA effort in the field. The facility will provide for the handling of radioactive isotopes, X-ray equipment, space environmental chambers, anechoic chambers, constant temperature rooms, and incubation rooms. Surgical suites and laboratory equipment will be provided. In this terminology, "suite" means the provision of a series of related facilities including an operating room, a preparation room, surgical storage, wash and scrub room, and so forth. In addition, instrumentation will be provided and developed for improved sensing of the many readings on bodily condition required during manned flight. The biomedical facilities will serve also to support the study of human subjects in the control and guidance simulators at Ames.

Nuclear Rocket Facilities

The facilities listed in table 27-VIII show NASA starting in the 1962 fiscal year. Actually, this is a joint program with the Atomic Energy Commission, expanding upon the facilities constructed by them and others. The facilities listed are concerned primarily with the nuclear rocket engine starting with Engine Test Stand No. 2 in fiscal year 1962 at the Nuclear Rocket Development Station (NRDS) in Nevada. The Engine Maintenance, Assembly, and Disassembly Building (E-MAD) and subsequent additions are related to an AEC facility also at the Nevada site but which is devoted entirely to the reactor. The reactor, engine, and flight test vehicle each requires its own development facilities. The Engine Test Stand is operated by remote control and after a firing the radioactive assembly is brought to the E-MAD by remote-operated train where it can then be disassembled and examined under safe conditions. It will be noted that additions to the E-MAD are also shown for both fiscal years 1963 and 1964.

TABLE 27–VII.—*Nuclear Rocket Facilities*

Name	Location	Fiscal year
Engine Test Stand No. 2	NRDS	1962
Engine Maintenance, Assembly, and Disassembly Building, and additions	NRDS	1962–1964
Nuclear Rocket Dynamics and Control Facility	Lewis	1963
Modification of Nuclear Aerospace Research Facility	Convair (Ft. Worth)	1963
Nerva Facilities	NRDS	1963
Hydrogen Heat Transfer Facility	Lewis	1963
Additions to Engine Test Stands No. 1 and 2	NRDS	1964
Radioactive Materials Handling, Decontamination, and Storage Complex	NRDS	1964

Parallel with this activity, the Lewis Research Center in fiscal year 1963 started work on a Nuclear Rocket Dynamics and Control Facility. In this facility, the reactor is simulated and the dynamic processes of control are studied. This facility is located at the Lewis Plum Brook Station.

In order to determine the effects of radiation on components of the nuclear rocket engine, an Air Force facility located at the Convair plant, Fort Worth, Tex., is being modified to meet NASA needs. Other facilities in support of the Nerva project at the Nevada site are also in progress in the 1963 fiscal year program. At Lewis in fiscal year 1963, a Hydrogen Heat Transfer Facility was started in order to determine the heat transfer coefficients in a rocket nozzle using liquid hydrogen as the coolant and propellant. In this case, the reactor is simulated by a heat source to obtain the necessary information.

In the fiscal year 1964 program, additions are proposed at the Nuclear Rocket Development Station in Nevada to existing Engine Test Stands No. 1 and No. 2. The additions and modifications comprise instrumentation and control items needed to facilitate the acquisition of data during closely scheduled test operations. These additions will reduce the time necessary to prepare and check out an engine before firing. An increased liquid hydrogen and process gas storage capacity is also proposed.

As the work load at NRDS has increased, the need for adequate facilities for radioactive material handling, decontamination, and storage has become more pressing. Such a facility is proposed in our present budget. The complex of facilities will provide fuel storage areas, hot engine hold area, a warm engine parts storage building, a decontamination building, and a temporary burial site for radioactive materials.

Electronics and Telemetry

Table 27–VIII indicates the facilities needed for electronic and telecommunication research to support OART programs. The Vehicle Antenna Test Facility was started by the Langley Research Center in fiscal year 1963 and an addition is proposed in 1964 to provide added capability. In the original facility are to be anechoic chambers for two different frequency ranges, and various other laboratory rooms for a more sophisticated approach to electronic research problems than had been possible previously. The addition proposed for fiscal year 1964 would provide the added capabilities of electro-optics rooms for the study of light as a communication medium with lasers, radio-frequency shielded rooms, and microwave instrumentation for research on more efficient spacecraft transmission systems, a laboratory for accurate frequency and power level measurement, cryogenic facilities for research on low noise amplification techniques, and laboratory space and instrumentation for research on advanced data acquisition and transmission components for spacecraft and ground systems.

TABLE 27–VIII.—*Electronics and Telemetry Facilities*

Name	Location	Fiscal year
Vehicle Antenna Test Facility and Addition	Langley	1963, 1964
Electronic Instrumentation Laboratory	Langley	1964
Electronics Research Center	-------	1964

An Electronic Instrumentation Laboratory is proposed also in fiscal year 1964 for Langley to provide facilities for research on microelectronics, development of thin film electronic components, and advanced research on measurement devices and techniques. These facilities will provide small environmental test chambers, dust controlled rooms, pressurized chambers, electron beam evaporators, and high-vacuum deposition systems. In addition, electro-optics rooms will be provided for the application of photoelectric and electro-optic techniques to hypervelocity flow instrumentation. This laboratory will contain equipment for the reliability testing of telemetry equipment and necessary laboratory standards for maintaining high accuracy instrumentation.

In view of the increasing need for electronic components to function satisfactorily in space environments over long periods of time and at the same time be of reduced size, weight, and power consumption, NASA is proposing in fiscal year 1964 to start on the design of a new Electronics Research Center. It will be the mission of this center to foresee and meet the requirements of future space systems for electronic and related physics research. It is intended that this center will serve as a focal point for advancing and directing related space activity in industry and universities in electronic and space communication research.

Space Propulsion Facility

Figure 27–2 shows a cutaway view of the Lewis Space Propulsion Facility now in the final design stage. In the center can be seen the aluminum vacuum chamber surrounded by a concrete outer chamber for protection against nuclear radiation. The facility will provide, as shown at the left, for assembling the vehicle for installation in the chamber. The chamber is shielded to permit nuclear space propulsion system operation under vacuum environmental conditions. Upon completion of the tests, the radioactive assembly can be moved through the chamber to a shielded disassembly area where the vehicle may be disassembled for inspection, disassembly, or maintenance. This facility will, as indicated previously, support research in the space power program and in nuclear electric propulsion.

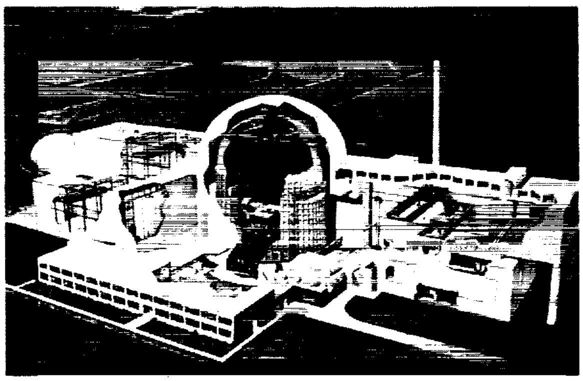

FIGURE 27–2.—Space Propulsion Facility, Lewis Research Center (Plum Brook).

CONCLUDING REMARKS

The research facilities described represent an initial investment of $198.5 million. In 1960, NASA's total research plant was about $500 million. Each of these facilities is built under contract, usually on a competitive-bid basis, and is a complete facility including equipment. Construction and operation are the responsibility of the field center indicated. Detailed information may be obtained by writing or visiting the appropriate field center.

Some 1,000 formal research reports and papers published by NASA scientists and engineers each year are largely the result of generalized and specific investigations in facilities such as these. Although these facilities are designed primarily to solve research problems related to NASA's mission, they are often used for specific investigations of special interest to other agencies and their contractors, such as the Department of Defense, the Federal Aviation Agency, and the Atomic Energy Commission, when the necessary capability does not exist elsewhere.

28 Tracking and Data Acquisition

GERALD M. TRUSZYNSKI

Deputy Director, Office of Tracking and Data Acquisition

The NASA is engaged in a wide variety of space exploration programs. The flight mission characteristics of these research programs, which in turn affect the requirements for the tracking of and collection of information from space vehicles, are correspondingly varied. The Office of Tracking and Data Acquisition is responsible for providing the ground instrumentation support for all NASA space flight programs. The following discussion will review (a) the functions of the Office of Tracking and Data Acquisition (OTDA) and its relationship with the other NASA program offices and centers, (b) the primary operational ground instrumentation networks that provide support to the NASA space flight programs, and (c) the presently programed and planned future augmentation of these networks necessitated by the requirements of upcoming flight programs.

The Office of Tracking and Data Acquisition reports to the Associate Administrator of NASA, in the same fashion as the four major program offices. (See fig. 28–1). The major program offices of NASA—the Offices of Manned Space Flight, Space Sciences, Applications, and Advanced Research and Technology—have under their control all the flight projects of NASA.

In November 1961, when NASA was reorganized, the Office of Tracking and Data Acquisition was established. It was recognized at that time, that since .tracking and data acquisition facilities can be used for multiprogram support, the ground instrumentation requirements for the various flight projects of NASA would require close coordination and direction by a central office to assure efficient

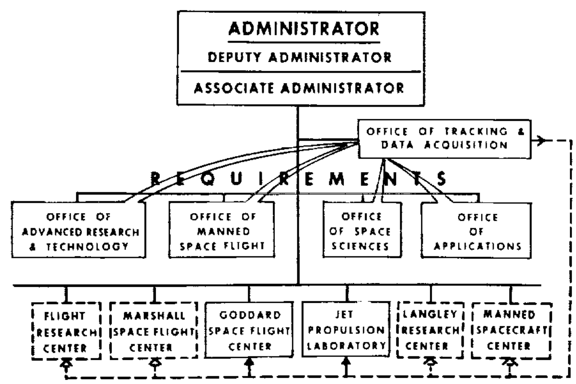

FIGURE 28–1.—Tracking and Data Acquisition, support function.

planning for the development, implementation, and operation of the network facilities required for support of the total NASA space flight effort. The primary role of the Office of Tracking and Data Acquisition is therefore to provide for and assure such support to all flight projects of NASA.

The Office of Tracking and Data Acquisition obtains from the program offices (and the NASA centers) requirements for the various flight projects. From these, an integrated support plan is developed. These requirements include the elements of tracking, data acquisition or telemetry, data display, and data processing and reduction as well as air-ground and ground-to-ground communications. In addition, the plans include some of the computation and command and control system elements necessary for the more complex projects such as Gemini, Apollo, the Eccentric Orbiting Geophysical Observatory, as well as those required by the unmanned lunar and planetary programs such as Ranger and Mariner. These integrated support plans are then implemented through certain of the NASA centers in terms of the facilities and network stations necessary to assure the proper support.

The development, implementation, and operation of the major tracking and data acquisition facilities and networks of NASA are carried out primarily by two of the NASA centers, the Goddard Space Flight Center in Greenbelt, Md., and the Jet Propulsion Laboratory in Pasadena, Calif. The Goddard Space Flight Center is responsible for facilities in support of the unmanned and manned satellite programs while the Jet Propulsion Laboratory is responsible for facilities in support of the unmanned lunar and planetary programs. Certain other tracking and data acquisition system developments are undertaken at the Langley Research Center and the Marshall Space Flight Center. The Flight Research Center operates an aerodynamic test network in support of the X–15 research airplane program. Finally (not shown in fig. 28–1) the Smithsonian Astrophysical Observatory in Cambridge, Mass., operates, under an NASA grant, a worldwide optical network of 12 Baker-Nunn cameras in support of certain scientific satellites.

Industry's relationship with NASA in achieving the necessary tracking and data acquisition support of the various NASA space flight projects can be expressed as follows: Normally NASA maintains overall system planning and conceptual design in-house. We rely on industry to supply the services necessary to construct, install, and operate the facilities and networks needed to meet our requirements in this area of effort. This approach, of NASA in-house system engineering and management together with industrial support to provide and operate systems is, we feel, the optimum solution to the problem of providing properly integrated, ground instrumentation systems. This has been demonstrated in such programs as Mercury, supported by the Manned Space Flight Network, and the Mariner, supported by the Deep Space Network.

The networks which are employed to provide the bulk of the ground instrumentation support functions are the Earth Satellite Network, the Deep Space Network, and the Manned Space Flight Network.

EARTH SATELLITE NETWORK

The Earth Satellite Network is the responsibility of the Goddard Space Flight Center. Figure 28–2 shows the location of the stations

FIGURE 28–2.—Earth Satellite Network.

of this network, an outgrowth of the original minitrack network established for the Vanguard Program of the IGY. It has been considerably augmented since NASA acquired it in 1958, and is now capable of supporting the class of so-called small scientific satellites which are characterized by minimum size and weight and, generally, the absence of an on-board data storage capability. Illustrative of these are such satellites as the Ionosphere Top Side Sounder and the Explorer series. This network has 13 stations and performs the tracking functions using interferometric techniques which have been well publicized in the literature. Data acquisition is performed using high gain Yagi antennas at frequencies of 136 to 137 megacycles.

In general, no major augmentations are planned in support of future small satellites other than procurement of certain specialized equipments necessitated by a particular satellite and the normal equipment replacement and updating. In the forthcoming generation of "observatory" class satellites, however, such as the Orbiting Geophysical Observatory and the Orbiting Astronomical Observatory, many more experiments are planned for installation on an individual vehicle than heretofore could be accommodated on a small scientific satellite. Data will be stored on-board the satellite for subsequent readout over a particular receiving station. The increase in the number of experiments planned for these larger, more complex, satellites results in a tremendous increase in the amount of data which will be transmitted from the satellite and hence be acquired by the earth stations. To accommodate these higher data rates and the highly eccentric orbits of satellites such as the Eccentric Geophysical Observatory which will travel to altitudes of some 60,000 miles, certain of the satellite network stations must be augmented with more suitable data acquisition facilities. These facilities take the form of large, self-tracking, parabolic antennas of 40- and 85-foot diameters to provide the required sensitivities. Figure 28–3 shows the locations of these particular facilities. This grouping of stations shown allows us to provide support for a variety of satellite orbital inclinations ranging from low through polar. These antennas are of an X–Y mount configuration and operate at frequencies of 136, 400, and 1,700 megacycles. An 85-foot antenna at Fairbanks, Alaska, is completed and undergoing checkout tests. Another 85-foot antenna is under construction at Rosman, N.C.

FIGURE 28–3.—Location of parabolic antennas in Earth Satellite Network.

The anticipated data acquisition workload on this first Rosman 85-foot antenna facility will grow steadily to the point where one antenna will be unable to meet NASA data acquisition requirements. This is a result of the types of orbits employed by the observatory class satellites, and the extremely long visibility time from this particular site. Therefore, a second 85-foot antenna is programed for installation there to alleviate the increased workload and to back up this critical station; construction will commence in fiscal year 1963. The three 40-foot antennas are in procurement with installation planned for completion by the end of 1963.

NASA is also installing two large 85-foot antenna facilities for the Nimbus Operational Satellite project, one in Fairbanks, Alaska, and the other in Nova Scotia. These facilities will be used to meet the command and data acquisition requirements of the joint NASA-Weather Bureau Operational Meteorological Satellite Program. Installation of the final 85-foot antenna in Australia has not yet begun but will commence in the next few months. With this combination of 40-foot and 85-foot antenna facilities we will be able to provide the necessary data acquisition support of the programed observatory class of satellites.

While the basic small satellite network provides the major *tracking* function for almost all the scientific satellites, certain of the high altitude, noncircular type with extremely long periods require specialized tracking equipment. To provide for this requirement, NASA has currently under development a range and range rate tracking system and associated transponder. Three of these facilities will be installed at network locations particularly suited to the trajectory of the Eccentric Geophysical Observatory.

Another required augmentation of the satellite network is the addition of PCM telemetry systems currently underway at some of the network stations. These PCM telemetry systems will provide the necessary data rate capability and measurement flexibility required for the planned observatory class satellites. PCM telemetry equipment is scheduled for installation at all the facilities having the new, larger antennas as well as at a few other selected network sites.

The collection of vastly increased amounts of data immediately results in the requirement to process and reduce these large quantities of information to useful form in a minimum time. Automatic data processing equipments are being developed by the Goddard Space Flight Center. Several of these Satellite Telemetry Automatic Reduction Systems (Stars lines) will be installed at Goddard in the coming year to handle the anticipated workload increase and additional lines will be required in succeeding years.

All the satellite network stations are linked by ground-to-ground communications links to a central communications center at the Goddard Space Flight Center. While the majority of these are of teletype, or at most, voice bandwidth capability, certain links must be very wide to allow transmission of received data from the station to Goddard and for transmission to the station of complex command data for quasi-real-time control of certain of the satellite functions. Such wide-band links, ranging from 100 kilocycles to 1 megacycle, will be installed at the major data acquisition sites on the North American continent. These links will be obtained by lease from the common carriers.

In summary, the equipment augmentation currently underway in the Satellite Network is given as follows:

(1) Large self-tracking antennas
  (a) 85-foot paraboloids
  (b) 40-foot paraboloids
(2) PCM telemetry
(3) Automatic telemetry handling equipment
(4) Digital command system
(5) Range and range rate tracking system
(6) Wide-band ground-to-ground communication links to major sites

Although we, at this time, do not plan for major new stations to support the unmanned satellite projects of NASA, it can be expected that certain additional augmentation to existing station equipments will be required to meet specialized requirements of future satellites.

DEEP SPACE NETWORK

The Deep Space Network is under the control of the Jet Propulsion Laboratory at Pasadena, Calif., and consists of three station locations spaced approximately 120° in longitude. These three stations are located at Goldstone, Calif.; Johannesburg, South Africa; and Woomera, Australia. Each station has an 85-foot antenna mounted on an hour-angle declination pedestal to provide coverage for the unmanned lunar and planetary programs. These stations were used for the Ranger and Mariner Programs.

The antenna used in the Deep Space Network is shown in figure 28–4. Note the typical hour-angle declination amount employed as the standard throughout the Deep Space Network. At the Goldstone site there are two such antennas.

The present Deep Space Network possesses an excellent capability for the unmanned lunar and planetary program. During the recent Mariner flight which culminated in a fly-by of the planet Venus in December, a new world record for long-distance communication was set using these facilities. However, the requirements of future projects in the unmanned lunar and planetary exploration program will require a significant improvement in this state-of-the-art network in order to satisfy the data acquisition requirements.

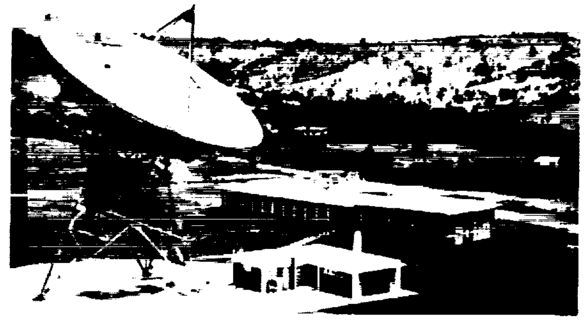

FIGURE 28–4.—Typical Deep Space Network station.

For example, the Surveyor project which is a second generation unmanned lunar explorer requires an increase of approximately 20 to 30 times in the data acquisition capabilities of the present network. To meet this requirement of increased data acquisition capability improvements of the present network equipments are planned. In addition to these technical improvements, additional antennas at the overseas sites will be required to meet the increased workload of the planned unmanned lunar and planetary projects.

Improvements programed for the Deep Space Network include conversion from the original L-band frequency to the S-band region in order to obtain an increase in gain from both the ground and spacecraft antenna. This will improve the data handling capability of the network by a factor of 5.6. In addition to this, ultralow noise traveling wave tube masers are to be installed to reduce the total system effective excess noise temperature thereby improving the system sensitivity. Further, Cassegrain optics are being installed on the 85-foot antennas to improve the total system sensitivity and to provide greater flexibility with regard to mounting masers and the transmitter power amplifiers. High-power diplexes will also be installed to permit the use of the same antenna for transmitting and receiving in a closed loop mode to provide ranging information to the space probe and for transmission of reliable commands.

Additional antennas will be installed overseas, one in Australia and one at a site in southern Europe; procurement of these will begin in the immediate future. These antennas will supplement the capability currently available with the Woomera and the Johannesburg antennas, and permit the increased data acquisition workload to be met. At these two additional antennas overseas and at one of the two antennas installed at Goldstone, precision ranging equipment will be added to meet the improvement in tracking accuracy required for the Surveyor and Mariner projects. The improvements underway in the Deep Space Network may be summarized as follows:

(1) S-band conversion
(2) Maser installation
(3) Ranging system
(4) High-power diplexers
(5) Cassegrain feeds
(6) Two additional 85-foot antennas
(7) Prototype 210-foot antenna

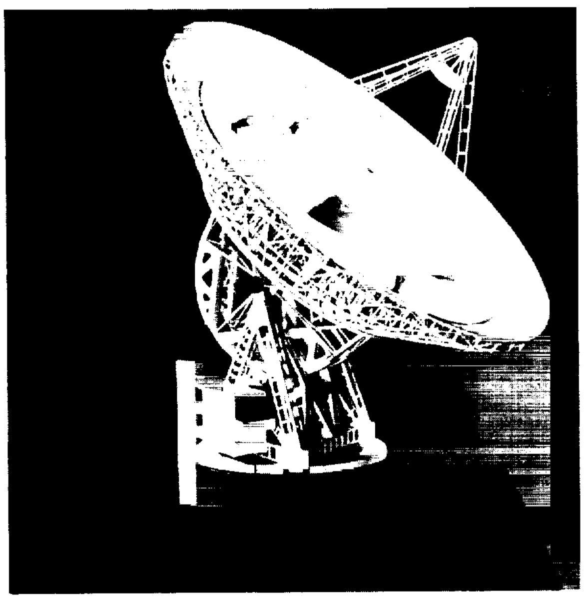

FIGURE 28-5.—Model of ground antenna, 210 feet in diameter.

With these augmentations to the basic 85-foot antenna system, the maximum economic growth capability of the 85-foot antennas is being approached. Construction of the first prototype of a new generation of ground antenna systems, approximately 210 feet in diameter, to support the future planetary program will begin shortly. A model of this antenna is illustrated in figure 28-5. It is an azimuth-elevation mounted antenna and will incorporate a Cassegrain feed structure.

The future plans regarding the Deep Space Network may be summarized as follows:

(1) Establish a three-station 210-foot network for 1968 time period
(2) Automatic station checkout equipment
(3) Specialized equipment as program requirements dictate

At some time in the future a network of 210-foot antennas will be implemented. The first prototype antenna planned for Goldstone will be one of this network of three stations. Plans call for this network of three 210-foot antenna stations to be operational in approximately the 1968 time period. In addition to the incorporation of the improvements previously mentioned, including the eventual 210-foot antenna network, automatic station checkout equipment to improve the total network system operational efficiency will be installed. An example of this is the automation of the servo checkout and other station functions to minimize the amount of time required for checkout of a station prior to the passage of spacecraft to be incorporated. It should be emphasized that the Deep Space Network requirements will continually be pushing the state-of-the-art in deep space communication systems.

MANNED SPACE FLIGHT NETWORK

The original Manned Space Flight Network designed primarily for use in the Mercury Program was composed of some 17 stations operated jointly by the NASA, Department of Defense, industrial contractors of this country, and overseas scientific and industrial organizations.

The basic philosophy employed in the design of this original network was that the system would use proven and reliable systems and components. In addition to this primary requirement of reliability there was a requirement for obtaining data in real or near real time. When manned flight is involved, safety dictates a more rapid determination of the conditions of the flight, hence the need for near real time trajectory determination as contrasted with the deep space missions and unmanned earth satellites where data can be obtained and the orbit computed at somewhat slower rates. This near real time determination of flight parameters and the desire to maintain maximum reliability fitted the capability which could be obtained with proven radar systems of that time.

This network has been very successful in supporting all Mercury flights to date. There has not been one exception in which the Mercury network held up a mission by a malfunction or equipment failure prior to or during a flight. The performance of this entire network has been most gratifying, and has exceeded the original expectations of this complex real time global tracking and data acquisition system.

We plan to build heavily on this existing basic network in progressively providing support to the upcoming manned space flight programs. There are the Gemini, orbital Apollo using the Saturn I and IB booster vehicles, and lunar Apollo using the Saturn V booster.

The new requirements placed on the Manned Space Flight Network by the Gemini program may be summarized as follows:

(1) Trajectory changes
  (a) Variable launch azimuth
  (b) Orbital inclinations 28° to 33°
(2) Two spacecraft
(3) Digital telemetry
(4) Spacecraft in-orbit control and command from earth

The trajectory changes, that is, the need to handle variable orbital inclinations resulted in the requirement for one additional station in the Manned Space Flight Network. This station will be installed at the antinodal point in the trajectory and is located at Carnarvon, Northwest Australia. An FPQ-6 radar is being procured for installation at this station. The requirement for tracking and data acquisition from two spacecraft in orbit simultaneously results in the addition of equipment at certain of the stations. Gemini, unlike Mercury, will require the transmission of an increased amount of data from the spacecraft to the ground facilities and vice versa. This increased quantity of data per unit of time, along with the fact that many of the transducers aboard the Gemini are digital in nature, makes the use of pulse code modulation techniques for telemetry more attractive than the FM/FM systems currently employed on the Mercury spacecraft.

Figure 28-6 summarizes the network additions which are presently being implemented for Gemini. Carnarvon, Australia, is the only new station required; augmentation of some of the existing Manned Space Flight stations will provide the total required support.

	GEMINI & AGENA TRACKING	GEMINI & AGENA TELEMETRY	GEMINI & AGENA COMMAND	GEMINI VOICE
PRIMARY GEMINI STATIONS				
CAPE CANAVERAL	○	●	●	○
BERMUDA	○	●	●	○
CANARY ISLAND	○	●	●	○
CARNARVON	●	●	●	○
HAWAII	○	●	●	○
TEXAS	○	●	●	○
GUAYMAS	○	●		○
SHIP (SE PACIFIC OCEAN)		●	●	○
SECONDARY GEMINI STATIONS				
ANTIGUA (LAUNCH PHASE ONLY)	○	●	○	●
SAN SALVADOR (LAUNCH PHASE ONLY)	○			
SHIP (SW INDIAN OCEAN)		●		○
CANTON		RECORD		○
WHITE SANDS	○			
KANO		RECORD		○
ZANZIBAR		RECORD		○
ASCENSION	○			
POINT ARGUELLO	○	RECORD		○
EGLIN	○			

○ EXISTING EQUIPMENT ● ADDITIONAL EQUIPMENT

FIGURE 28-6.—Manned Space Flight Network, Gemini support.

This augmentation will take the form of the installation of dual PCM telemetry systems, dual acquisition antennas, dual digital command systems, and a radar coder to provide tracking capabilities of one spacecraft when two are in close proximity. It should be noted that only seven of the existing Manned Space Flight stations will be augmented to provide the support for Gemini. Experience obtained from the previous Mercury flights enables this reduction in the number of primary stations. The remaining stations of the Manned Space Flight Network will be used essentially as now configured to provide additional voice communication to the astronaut and other backup functions.

This same network as augmented for the Gemini program is planned for support of the orbital Apollo program utilizing the Saturn I and IB launch vehicles. One major addition to the primary stations planned is the installation of what we call the unified S-band system. For the subsequent lunar Apollo program, the use of such a system is dictated by the distances involved and consequent need for higher gain ground and spacecraft antennas and reduction of overall system weight and complexity. The unified S-band system will enable all functions of tracking, data acquisition, voice, and television to be performed by one transponder aboard the spacecraft. Thus significant weight reductions and improvement in the reliability of the total system can be provided by a duplicate transponder aboard the spacecraft—capable of taking over all functions in the event of a failure of the one in use. Duplication of multiple subunits as they exist on Mercury today will not be required.

Table 28–I summarizes this consolidation of functions. In order to qualify this system properly before its actual use on lunar flights, they will be installed and operated during the orbital test phases at the primary stations. During the lunar flights, they will be required for support of the parking orbit phase of the mission. It is expected that antennas of the order of 30 feet in diameter will be utilized at these sites and should be capable of providing coverage for a significant portion of the trans-lunar trajectory. At greater and near-lunar distances, coverage will be provided by three 85-foot antennas which are planned for installation at existing Deep Space Net station locations in order to allow the use of these existing antennas for backup purposes. Initial procurement of prototype unified S-band equipment is planned to commence shortly with total procurement for the final operational network planned for fiscal year 1964.

An additional coverage requirement for the Saturn IB orbital and V lunar missions is that of tracking and data acquisition during the insertion into earth orbit and subsequent injection into the lunar transfer trajectory. The fact that these events occur over geographical areas where land stations are not possible requires the use of tracking ships to provide the required coverage. NASA plans in fiscal year 1964 to begin procurement of three instrumented ships configured for Apollo requirements to provide the data coverage in these critical portions of the mission.

TABLE 28–I.—*Summary of the Functions of the Unified S-Band System*

Function	Mercury Spacecraft	Apollo Lunar Spacecraft
Tracking	C-Band Radar Transponder	
	S-Band Radar Transponder	
Telemetry	VHF Transmitter	Unified S-Band Transponder
	VHF Transmitter	
Voice (S/C to Earth)	UHF Transmitter	2,100-megacycle region, earth to S/C.
	HF Transmitter	
Voice (Earth to S/C)	UHF Receiver	2,300-megacycle region, S/C to earth.
	HF Receiver	
Command and Up-Data	UHF Receiver	

The planned augmentation of the Manned Space Flight Network to provide for the Apollo program may be summarized as follows:

(1) Several translunar antennas
(2) Three 85-foot lunar antennas
(3) Unified S-band system at primary stations
(4) Three tracking ships

Planning is still underway in the area of reentry and network requirements are not yet available. Note that this plan for support of the total manned space flight program stresses primarily an orderly development of network capability based on systems which are not beyond the state of the art. Our progressive augmentation schedule allows these systems to be properly qualified for final use and, most important, utilizes as much of the cumulative operational experience as possible which is felt to be a major asset in assuring reliable ground instrumentation support to this critical program.

CONCLUDING REMARKS

In general, most NASA tracking and data acquisition stations in the three major networks are operated by contractor personnel. In certain foreign countries such as Australia, South Africa, the United Kingdom, and Canada, the stations are operated by indigenous personnel under agreements with the foreign governments. Contract operations are also performed for NASA in the areas of data processing and the operation of certain communications terminals. The widespread communications links which are required to tie all the network stations into the central control centers are obtained by lease from the common carriers or through the use of some Government-owned services. NASA does not have, nor has it planned, the installation of large-scale Government-owned communications systems. Rather, a practice of leasing communications circuits to provide for interstation communications requirements is expected to continue.

In fiscal year 1963, some $173 million are required in the area of tracking and data acquisition support for the development, implementation, and operation of the facilities we have described. This amount will increase to some $349 million as reflected in the current budget request for fiscal year 1964. Industry is invited to participate whenever possible in providing the equipment and operating capabilities we need to perform this vital ground instrumentation support function to the space flight program.

29 Technical Information Service for Industry

MELVIN S. DAY

Director, Office of Scientific and Technical Information, Office of the Administrator

The information generated by the scientific and technical information programs of NASA is not only a record of knowledge gained through research but also provides a working guide to understanding directions in which NASA developmental interests are moving. Our scientific and technical information program recognizes that this information must be communicated in a very timely way and on the widest practicable basis both within and outside the aerospace family. We accept the premise that information requirements which NASA must satisfy can be met only by a system that assures ready access for science, for industry, for the educational world, and for the general public to NASA generated scientific knowledge appropriate to a given need.

The mere availability of information is not enough. The information must be so collected, repackaged (when necessary), and distributed that NASA's many publics can secure the utmost benefit.

The services and products of the NASA scientific information program, which is discussed briefly in this paper, permit industry to keep apace with highly diversified and changing NASA requirements. These tools were developed for use in the field, and, specifically, to be of immediate value to the researcher, the engineer, or, in general, the ultimate user of scientific data. Each participant in the national science and aeronautical programs should have at his immediate disposal the information services, the products and tools, to use *locally* in support of his work. Thus, this principle which emphasizes local access guided the preparation of NASA's announcement journals, supporting indexes, information retrieval programs, and other technical information services available to the industrial participant in our programs as well as to other segments of the economy not presently participating in the aerospace development program.

In this review of the technical information program, it should be remembered that the various services and products are made directly available and without charge to those whose work is in support of or of direct interest to the NASA research, development, and operational efforts. These services are normally extended to research, manufacturing, and consulting firms which hold NASA contracts, to NASA consultants, and to recipients of NASA grants. These same products and services also are or will be available at a nominal charge to those groups having an interest in space and aeronautics but which are not involved in a contractual relationship with this Agency.

SCIENTIFIC AND TECHNICAL AEROSPACE REPORTS (STAR)

NASA announces its research and development reports in a basic journal titled *Scientific and Technical Aerospace Reports*, known generally by its acronym *Star*. (See fig. 29–1.) *Star* is a comprehensive abstracting and indexing service devoted solely to "report literature" bearing on the science and technology of aero-

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nautics and space. It is published twice each month to announce:

(1) Scientific and technical reports of the National Aeronautics and Space Administration, its contractors, and grantees.

(2) Scientific and technical aerospace reports of government agencies, universities, and industrial research organizations in the United States and abroad.

Star is arranged in two major sections to increase its usefulness. The first section contains abstracts of research and development information arranged in 34 general subject categories for ease of scanning. The second section comprises four indexes to provide convenient methods for information identification: subject, corporate source (designates the organization at which research is conducted), author, and report number. This subject index is of a *Chemical Abstract* type and is used both as a retrospective searching tool and as a current scanning device to assist users in identifying newly announced items of significance.

Additionally, and to assure that the announcement journal *Star* remains a current desk tool, all four indexes are cumulated on a quarterly, semiannual, and annual basis. These cumulations are issued within 2 to 4 weeks after close of the period they cover. For example, the annual index for calendar year 1962 was issued in January 1963, just 3 weeks after the close of the period it covers.

This journal is a basic building block in any program designed to keep abreast of the expanding knowledge in aerospace science. It is also of critical importance to those companies which are exploring a potential relationship with NASA in its broad research and development programs.

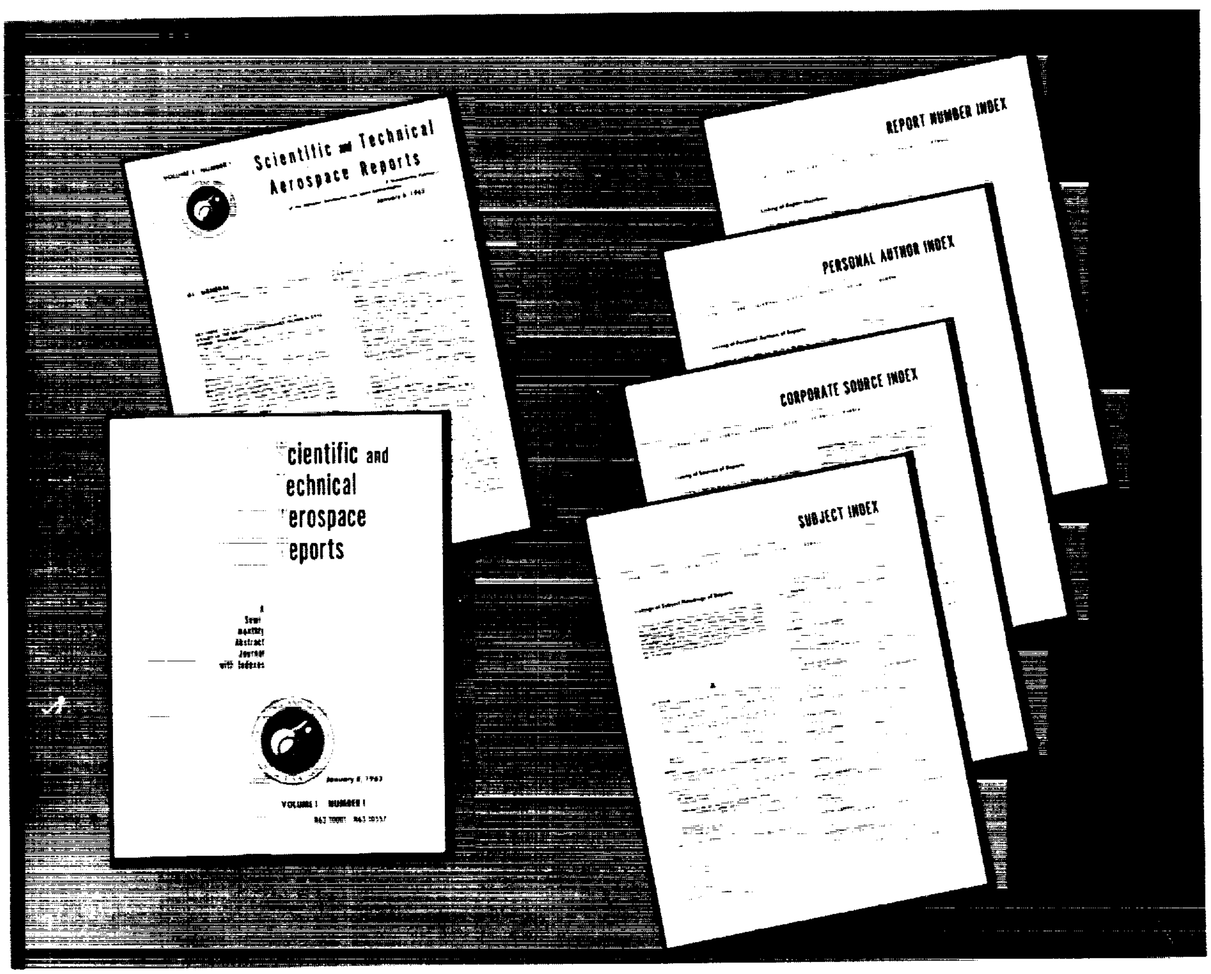

FIGURE 29-1.—Scientific and Technical Aerospace Reports.

In order to assure that information is received on a timely basis, the publication cycle is such that all items received within any 2-week period are announced in this journal within 4 to 6 weeks following their receipt by our processing group.

Star is available routinely and free of charge to NASA contractors, subcontractors, grantees, and consultants. In addition, it may be purchased by the public from the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C.

AVAILABILITY OF NASA SCIENTIFIC INFORMATION

NASA disseminates information developed in its many scientific programs on a very broad basis. NASA is understandably concerned with the prompt availability of its research reports to the aerospace community. The announcement, through an abstract, of the existence of knowledge is only a partial step. Of greater importance is the availability of the specific document in which the information appears. The NASA documents listed in *Star* are routinely available on an automatic basis, either in full size or on microform copy, to NASA contractors from the Office of Scientific and Technical Information.

This automatic distribution may be either comprehensive or selective depending on the stated needs of the individual user organization. Again, this automatic distribution is in keeping with the principle of maximum local access mentioned previously. Its objective is to provide immediate local access to reports of interest without the delay of requesting them from geographically distant points. Backing up this initial automatic distribution, NASA answers specific requests for individual reports of interest to its centers and contractors.

NASA technical documents and bibliographic tools are deposited in 12 Federal Regional Technical Report Centers to furnish those interested in aerospace information such services as personal reference, interlibrary loans, photocopy, and service and assistance in obtaining retention copies of NASA documents. NASA publications are also currently being forwarded to major public libraries throughout the United States. A complete listing of all these libraries may be found in each issue of *Star*.

In addition, and for those who are not directly participating in NASA programs, NASA reports may be purchased from the Superintendent of Documents or the Office of Technical Services in the Department of Commerce. The abstract of each report in *Star* indicates which availability source should be utilized.

Those interested in NASA "Policy and Procedures for Distribution of Scientific and Technical Information" may obtain an informational kit upon request from the NASA Office of Scientific and Technical Information.

INTERNATIONAL AEROSPACE ABSTRACTS (IAA)

The preceding discussion has covered the results of our national aerospace program appearing in research and development reports. It should be recognized, however, that there is a significant body of aerospace science information bearing on NASA programs and interests which appears in the journals of professional and learned societies, technical periodicals, and books.

As previously noted, *Star* abstracts and indexes the report literature on a worldwide basis. The world's journal and book literature in aerospace science is abstracted and indexed by the American Institute of Aeronautics and Astronautics (formerly Institute of the Aerospace Sciences) and is published in their announcement journal, *International Aerospace Abstracts* (*IAA*). (See fig. 29–2.)

Significant modifications became effective on January 1, 1963, through a cooperative agreement between NASA and the Institute for access to the vast body of aerospace information.

In order to make it as easy as possible for anyone to obtain the information he needs, the abstracting and indexing services provided by NASA and the Institute have been coordinated and so integrated that information is almost literally at one's finger tips.

This is how the abstracting and indexing system works: Both the *IAA* and *Star* use the same makeup and the same indexing techniques so that the reader can readily utilize both journals. Cumulated indexes to each journal are prepared and issued promptly on a quarterly basis, with the second quarterly being a semiannual index, and the fourth quarterly being an annual index.

Both journals are issued twice each month. *IAA* is published on the 1st and 15th of the month and *Star* is released on the 8th and 23d

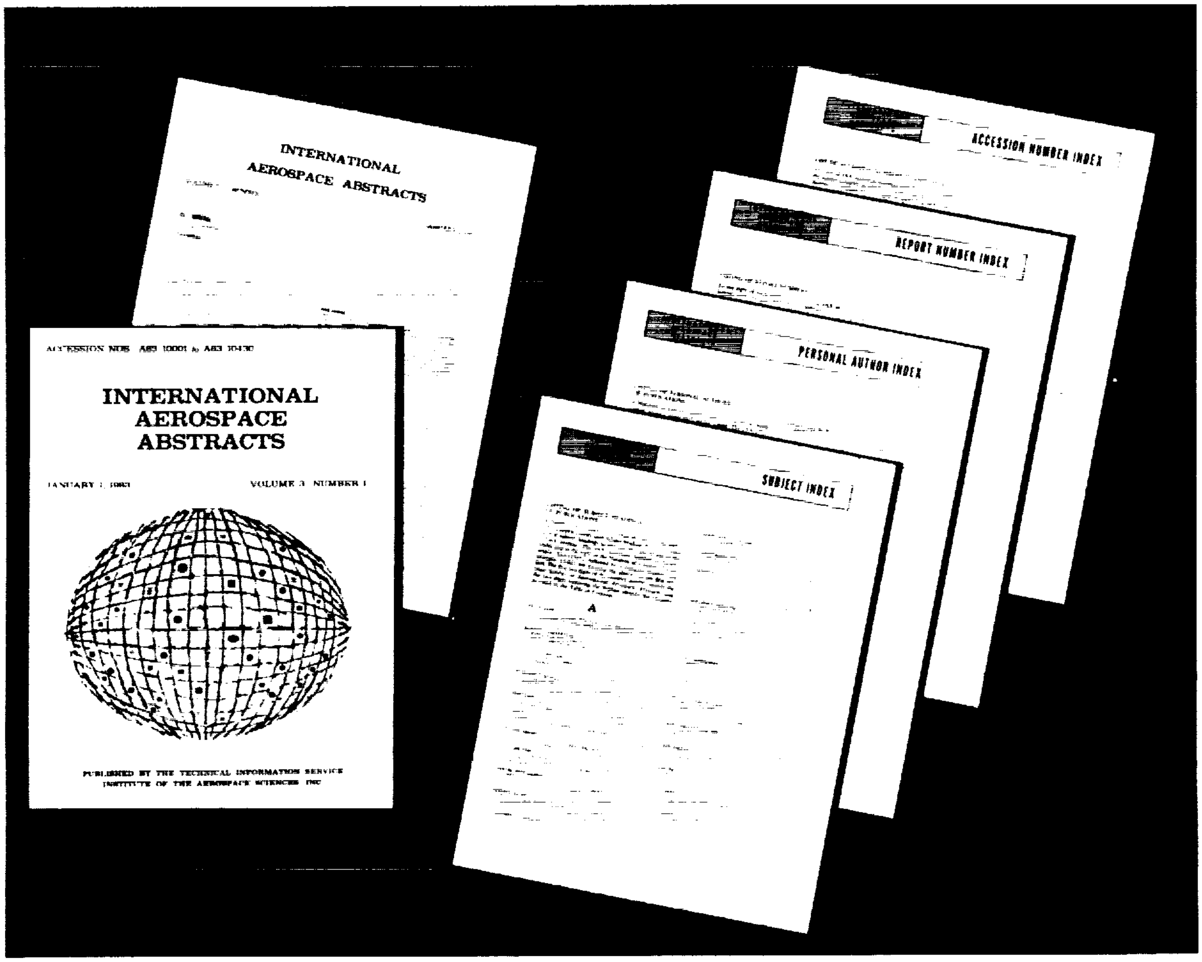

FIGURE 29-2.—International Aerospace Abstracts.

of each month. Thus, the aerospace community now has available, four times a month, information about the world's literature in aerospace activities. (See fig. 29-3).

The *IAA* is available at no charge to NASA contractors as part of the information support routinely provided for effective contractor performance. This journal is also available to those interested in the field of aeronautics and space technology on a subscription basis from: American Institute of Aeronautics and Astronautics, 750 Third Avenue, New York 17, N.Y.

This cooperative undertaking with a major professional society in this scientific area should during 1963 bring some 40,000 scientific articles to the attention of busy scientists, engineers, and librarians in a most useful and available form.

INFORMATION PRODUCTS AND SERVICES

In additional to the various informational tools produced routinely in the NASA scientific and technical information program, reference services are available to meet the needs of the engineer, scientist, company, or laboratory working in the national aeronautics and space effort. These operations are designed to satisfy both generalized and highly specific requests for information assistance. (See fig. 29-4.)

Utilizing computer techniques, NASA prepares bibliographies in selected subject areas on a continuing basis and special bibliographies to serve information needs of individual re-

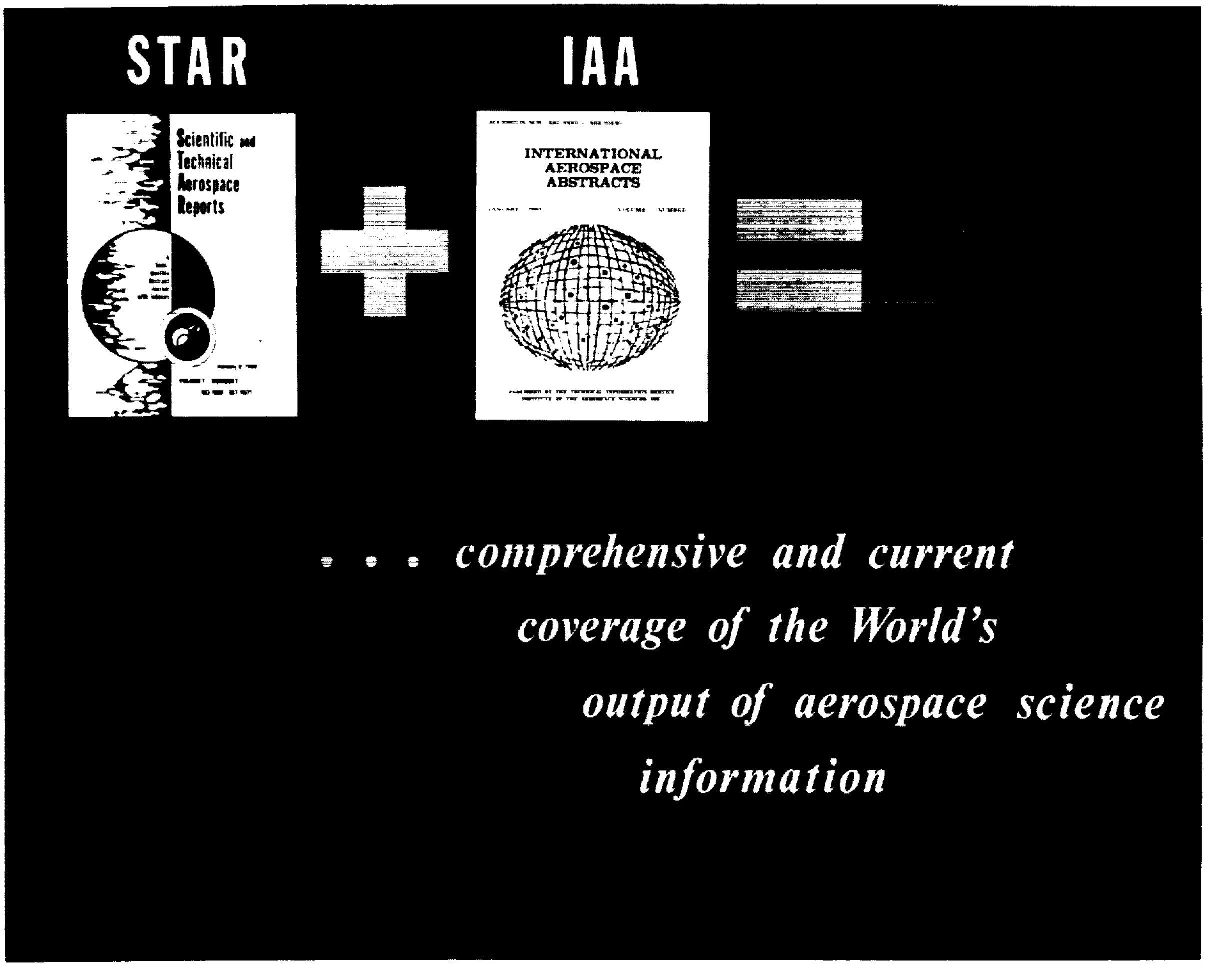

FIGURE 29–3.

questors. This general literature search service is available on a routine basis to NASA contractors.

There are many other important information program elements which contribute toward bringing vital information into the hands of our many publics on a timely basis. The expanding translation program, the organization of project type information, the repackaging of information for the industrial economy and the educational community, handbooks, source books, and state-of-the-art summaries all bear distinctly on the basic information requirements of the aerospace age.

CONCLUDING REMARKS

This broad-brush treatment of the NASA scientific and technical information program summarizes for NASA contractors the services which may routinely be expected from the National Aeronautics and Space Administration. Information products now currently and publicly available to those who intend to remain abreast of aeronautics and space technology have been described. Further information concerning this program may be obtained from the Office of Scientific and Technical Information, NASA, Washington 25, D.C.

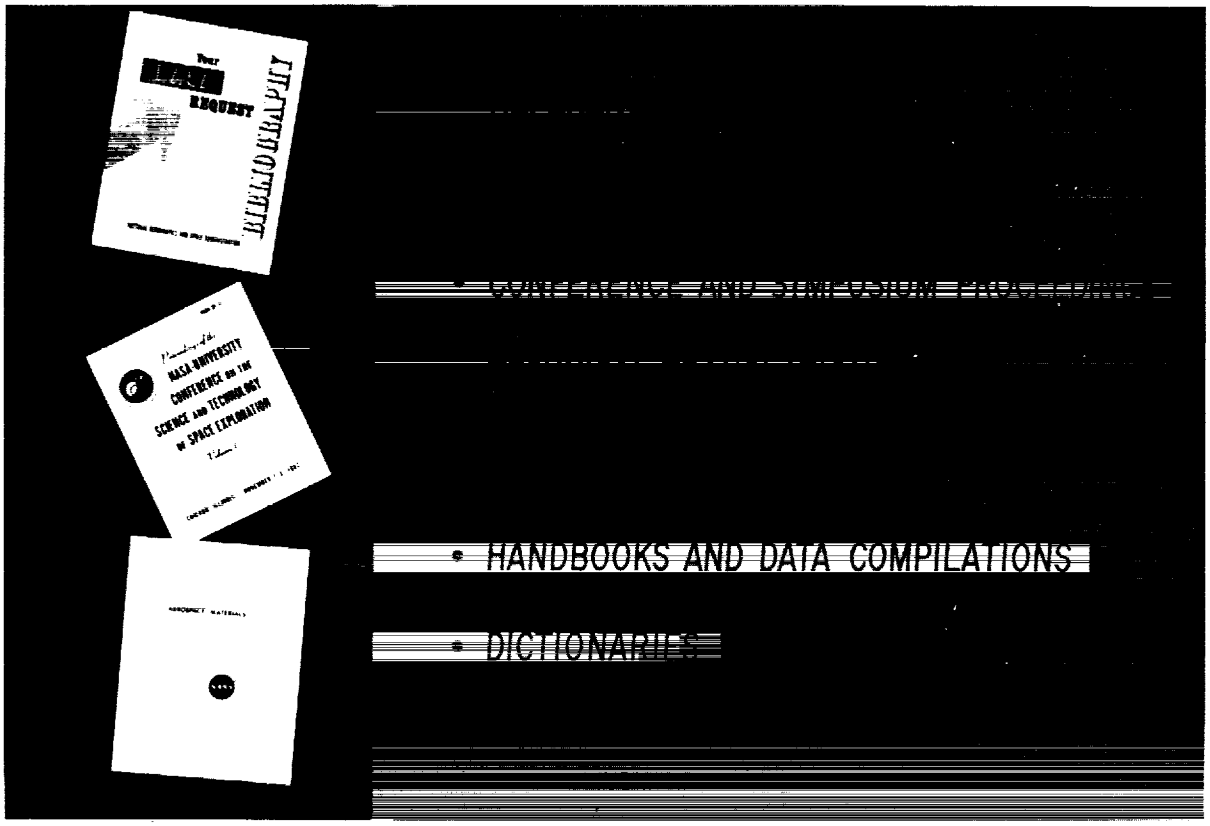

FIGURE 29-4.—NASA information products and services.

30 Unsolicited Proposals

CARL B. PALMER
Chief, Sponsored Research, Office of Grants and Research Contracts, Office of Space Sciences

The Office of Grants and Research Contracts has two primary missions in the NASA sponsored research and development programs. One is to develop policies and procedures for grants and contracts with nonprofit scientific and educational institutions and to issue such grants and contracts. The other is to receive, catalog, and insure the proper handling of unsolicited proposals from all sources. This paper will concern only the latter mission.

The booklet "Selling to NASA" describes briefly the procedure for submitting research proposals without any formal advertising or request-for-proposals from NASA. Such unsolicited proposals are received in this Headquarters from a seemingly unlimited variety of sources and cover an equal variety of subjects. They are presently being received at a rate of nearly 250 per month totaling $30 to $35 million, and the rate is increasing. These figures do not include the occasional multimillion dollar proposal to design a gravity reverser or similar exotic device. This adds up to nearly 3,000 proposals per year with an aggregate price in the vicinity of $400 million. A sizable majority of these proposals are submitted by educational and nonprofit scientific institutions. Grants, contracts, and interagency fund transfers will be issued to the extent of possibly 20 percent of the dollar value of these proposals, and past experience indicates that approximately 20 percent of these obligations will be to industrial organizations.

A proposal influx of this magnitude obviously requires some provision for central control and standardized procedures. Accordingly, the Office of Grants and Research Contracts was designated as the single point in NASA Headquarters to receive and to coordinate the review of all unsolicited proposals to this Headquarters.

It should be noted that unsolicited proposals are especially appropriate for basic and applied research. They are less suitable for development projects, and highly inefficient for selling existing hardware. For hardware, if the item offered is not needed, it will not be bought; if a well-defined requirement exists, invitations to bid should already have been issued. For research, results cannot be specified in advance so there is little basis for formal competitive procurement. Therefore, the scientist prepares a proposal convering the research that he is eager to do and submits it to an appropriate potential sponsor.

The size or format of unsolicited research proposals is not specified. Their purpose is to tell our scientists and engineers what the proposer wants to do, how he will try to do it, what results might be expected, and what it will cost. It is generally beneficial to the proposer to present this information clearly and concisely.

The technicalities of unsolicited proposal writing are not appropriate to this discussion. However, those interested in some thoughts on the matter are referred to the article entitled "Writing the Unsolicited Proposal" in the October 1962 *STWP Review*, a quarterly publication of the Society of Technical Writers and Publishers.

Figure 30–1 should help in understanding the handling of unsolicited research proposals by NASA Headquarters. The "shot-in-the-dark," or cold, proposal is submitted directly to the Office of Grants and Research Contracts, usually because the proposer believes that NASA is—or should be—interested in a particular investigation. The "reconnoitered" proposal may, on the other hand, be preceded by informal discussion with individuals or groups within the Administration, in order to help correlate the company capability and the Administration interests. The fact that the proposer has taken the trouble to become informed of technical areas of greater or lesser Administration interest, and may have been encouraged or discouraged to various degrees prior to submitting the proposal, does not remove the proposal from the "unsolicited" category.

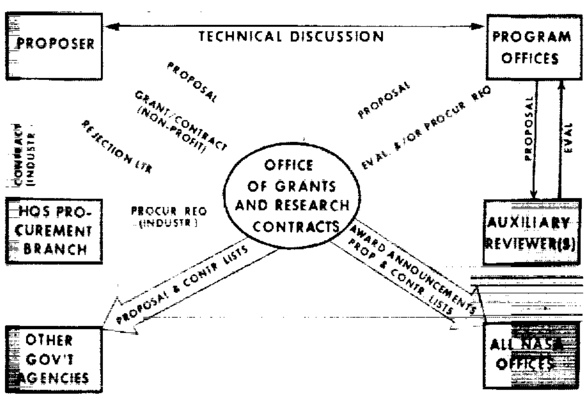

FIGURE 30–1.—Unsolicited proposal procedures, basic structure.

Ten copies of the proposal should be submitted to the Director, Office of Grants and Research Contracts. In his office the appropriate files and identification will be established, and the proposal will be reviewed for technical content and related to the needs and interests of the various Program Offices within NASA Headquarters. It will be distributed for simultaneous evaluation by all potentially interested Headquarters Program Offices; these Offices, in turn, may request technical evaluation in depth from one or more of the NASA research centers. The bulk of the review is handled inhouse, although outside advice may be sought on occasion. When submitting a proposal, the proposer should identify the individuals or groups in NASA with whom the research has been discussed to insure that they will be included among the reviewers. If they have so requested, information copies of the proposal may be sent to them at the same time the "official" proposal is submitted to the Office of Grants and Research Contracts.

If no one can support the proposal the rejection letter is issued from the Office of Grants and Research Contracts. If a Program Office does wish to support the proposal the procurement action papers backtrack through the Office of Grants and Research Contracts. There, the staff terminates other review activities on the propsal that may be underway, assembles all available relevant information with official copies of the proposal, and (for industrial proposals) forwards the total case to the appropriate procurement office for negotiation. The proposer is informed when cognizance is transferred to the procurement office.

Processing a proposal, from submission to either rejection letter or executed contract, is necessarily time consuming. The period varies widely from proposal to proposal, depending upon the time of year, whether the project is new or a renewal, the number of Program Offices considering the proposal, and the complexity of the negotiation. The average processing time is now longer than 6 months; we recognize this as unduly long, and we are striving to reduce the time as much as possible.

Quarterly and monthly reports, not only of the active grants and contracts, but also of proposals that are under review, are prepared and distributed for NASA-wide use and for coordination with other Federal agencies. The proposal lists, however, are not made available to the general public.

Proposals for follow-on research significantly extending or expanding the scope of an existing contract should be submitted through the Office of Grants and Research Contracts just as in the case of a proposal for a new project.

31 Program Control Techniques

THOMAS E. JENKINS
Director, Management Reports, Office of Programs

The impressive scope and complexity of the NASA program is certainly obvious from the descriptions given in preceding papers. The execution of this program requires that all industry and government participants utilize management techniques which will insure the most effective use of available talent and resources to achieve these objectives. Resources are scarce in terms of the right kinds of talents and know-how, as well as the dollars required to do the job. Therefore, management at all levels must exercise intelligence and careful planning to achieve the qualitative and quantitative performance desired.

These statements gain further meaning when one considers the uncertainties and constraints with which space program management in government and industry is faced. It has been popular for some time to list three general variables—time, cost, and performance—as being characteristics in the management of most enterprises. In determining NASA's needs for formal management control techniques it is necessary to begin by examining these three factors in terms of the uncertainties of each in relation to the NASA program and the constraints imposed by each and in combination as they might affect the ability of management to pursue alternate courses to solve problems as they occur.

First, consider the time factor. It is well known that in any program which is primarily research and development in character, time is a variable with which one must always reckon because of the inability to estimate accurately the time required to solve the many technical and logistic problems to be encountered. The complexity involved in managing and controlling the time variable is a function of the interrelationships and interdependencies which exist in various parts of a hardware system, project, or total program. Time is also a constraint, because for various reasons we do not have unlimited or even a comfortable amount of time in which to accomplish various program objectives. For instance, for reasons of national policy, manned exploration of the moon is planned within a finite time span, this decade. Nature itself imposes time constraints which must be met. For example, Mariner II was very successful but only because a development program spanning several years produced hardware with the right performance characteristics on time to keep a rendezvous with Venus when the opportunity presented itself. The constraint imposed by the performance characteristics of the available launch vehicle in relation to the weight of the Mariner spacecraft limited this opportunity to a very narrow window of about 6 weeks in the summer of 1962. Thus, the variables of time and performance interacted to define management's task. In most of the NASA program, whether it is within the work on a single contract, a major system within a project, or one project as against another, management must continually assess and decide trade-offs of time versus performance. However, in most parts of the program, there are real limits within which variations in desired performance can be allowed in order to meet schedules. For example, the open and well-publicized Mercury Project exposed the general public to management decisions, at least at the launch site, based on the cardinal premise that performance could not be sacrificed in favor of an early but riskier launch. The management decisions made in the glare of publicity at the launch site had been preceded by a painstaking development program spanning several years in which many management decisions had been made in favor of minimizing risks and insuring performance.

In the case of a manned space vehicle the reason for minimizing technical risk in performance characteristics is very obvious. In other kinds of projects the degree of specified performance which must be achieved becomes a more subtle management consideration but nonetheless real. The myriad of worthwhile objectives places the highest level of management under continuing pressure to choose among targets in a logically programed time sequence.

After work has begun, the selected objectives generally have to be reshaped, modified, and reevaluated as the job is executed and the time, performance, and the third variable—cost—become more definitive. Actual consumption of resources, or *cost*, must be controlled within limits of essentially two kinds. The first is the constraint imposed by the funds available for all projects. The second set or subset of limits is more difficult to perceive and manage because it stems from the internal competition among segments of the project or program for a larger share within the fixed total available.

The program dynamics which management must control in terms of time, performance, and dollars, each factor acting as an uncertain one and also as a constraint in mixed fashion, demonstrate the need for formalized management information and control techniques which continually provide management with a factual basis to redefine—in terms of newly developed conditions—the job to be done, the cost of doing it, and the time allowed and available to do it in, and feed back to program participants authoritative and adequate guidance and direction.

Management control techniques are a must but these cannot do the management job much less automate the management job. The basic tenet of NASA in this area is that technical and managerial competence resides in people and not in management systems. However, in this large complex undertaking which must operate in a coordinated fashion, greater reliance must be placed on formalized management systems designed to be used by, and to assist, the manager.

Also basic to NASA's philosophy and practice of management is that a change in the total scope and dollar value of the program does not necessarily have to be accompanied by a proportional change in the number of people on the Government side to discharge the responsibility for executing the program. Figure 31–1 rather dramatically illustrates the point. Using 1961 as the base this shows that NASA's in-house staff has decreased steadily over the years in relation to the total program dollars. This has been accompanied by the enlistment of an expanding industrial base to execute and support the program. The design of NASA's formal management systems and practices must, therefore, include contractor participation as an integral factor. It further places on NASA the responsibility to design its basic management and control techniques to be as compatible as possible with existing industry practices and yet be responsive to NASA's management needs.

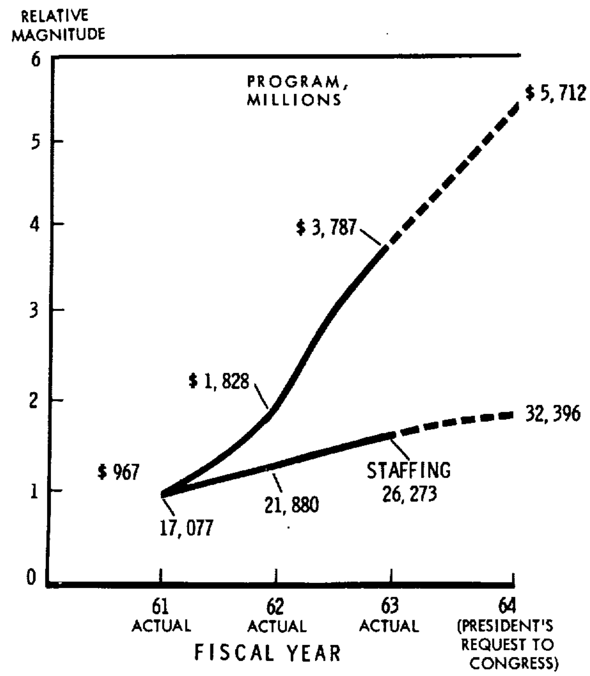

FIGURE 31–1.—NASA program and staffing growth.

It is in NASA's major R&D flight development projects and major facilities, where the bulk of the program is performed by industry, that the interrelationships of schedules, cost, and performance become most complex, where the continual redefinition of objectives is inherent in the effort, and, consequently, where the strongest need exists for dynamic and integrative management tools.

To meet this need, it has been NASA's policy to develop uniform management and information systems for agency-wide use, to keep the number of these systems to the practicable minimum required to serve NASA's management needs, and, to involve contractors from a reporting standpoint only to the extent necessary to provide NASA with essential information on job status, resources usage requirements, and progress in achieving specified technical characteristics and performance levels. The basic theme used in the design of our management systems is that total project management is best achieved if the three management variables—time, cost, and performance—are managed and manipulated on a common framework which classifies all work elements of the project in a pyramidal, hardware oriented management framework with successive tiers representing in logical fashion the successively detailed layers or subdivisions of the project. This is called the project work breakdown structure. Figure 31-2 illustrates a typical flight or mission project work breakdown structure and shows the successive tiers of items making up the total project which must be managed in unison and in a coordinated fashion to achieve the overall project objective. If it is assumed that time runs from left to right on the pyramid, status can be measured by breaking each horizontal element into significant milestones and charting progress as time passes. It is obvious that each subdivision of work on this pyramid can also be established in the accounting system as a cost collection or summarization category, in addition to being the framework for cost estimates. (This can be preceded by the buildup of an estimated cost by estimating the cost for each of the items represented.) This common framework of milestones and cost categories allows a correlation of these two management variables, at least in a very crude way. The preceding discussion broadly describes one of the three basic systems through which NASA asks its contractors to report project progress—our project milestone system, with a companion cost report which relates the subdivisions of cost to a given series of milestones.

Straight milestone systems require a great number of charts for display purposes and do not portray the interrelationship between and among the milestones or where interfaces may exist between one part of the job and another. The interdependency of milestones within the total job cannot be readily assessed. Therefore, a second basic NASA system through which contractors are asked to report is the NASA Pert system, again with a companion cost report. The NASA Pert system is designed to be used primarily at the NASA project manager's level to serve the project manager in:

Coordination of project planning
Managerial control
Assessment of project status
Programing
Coordination of progress data

In the NASA concept, the system is designed primarily to aid the project or system manager in tying together the total project or system for which he is responsible. For instance, in our sample, Project Daedalus (fig. 31-2), the Spacecraft System Manager is responsible to the Project Manager for development of the spacecraft as a part of the total project. Note that at the third tier of the project work breakdown the spacecraft is composed of five subsystems, which the systems manager must develop and integrate into a working whole. In planning the work, defining interfaces, assigning the work (including that to contractors), and providing a means for ready assessment of status with a minimal reporting burden, use of the NASA Pert and Companion Cost system

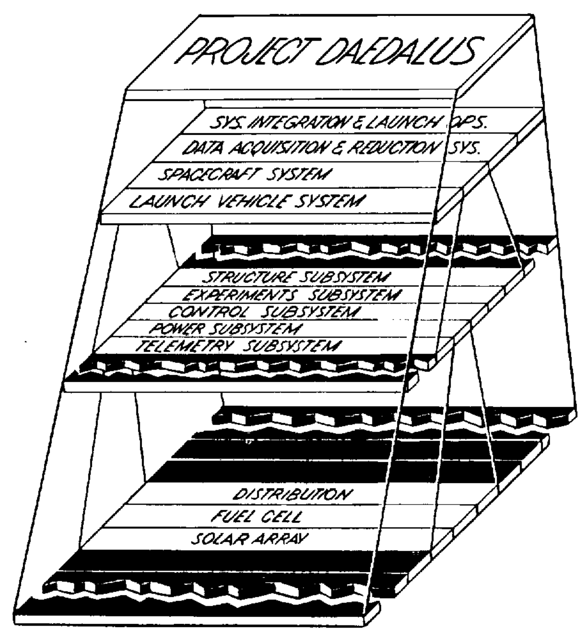

FIGURE 31-2.—Work breakdown structure.

provides the manager with a usable tool. As previously mentioned, the Spacecraft Systems Manager must manage work on five subsystems and these together must be integrated into the total project plan by the project manager. Figure 31–3 shows that part of the total project

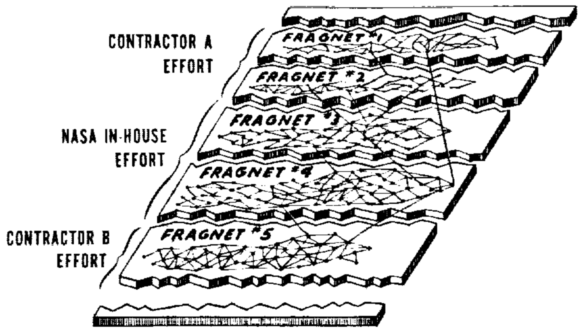

FIGURE 31–3.—NASA project network.

network which represents the Spacecraft Systems Manager's responsibilities. Each of the five segments of the project plan labeled "fragnet" represents a major subsystem of the spacecraft system. As can be seen by the activity lines which go from events in one fragnet to events in another, the total spacecraft job is interconnected using Pert logic diagramming which displays interdependencies and interrelationships. The NASA system is designed so that the project manager can get a progress reading on an individual fragnet separately, or a progress reading on the total project. The scope of the fragnets is determined by the breakdown of the job on the pyramid shown in figure 31–2. As in the NASA milestone system, the companion cost planning and reporting principle applies since in both systems the common management framework or project work breakdown structure is the starting point. In NASA Pert and Companion Cost a cost account is established for each fragnet as shown in figure 31–4. The figure indicates that the minimum acceptable level of time-cost correlation for adequate management control in most flight development projects is at the subsystem level of project work breakdown. In potentially troublesome areas of the project, involving highly uncertain developments, for example, a finer screen is used as shown in figure 31–5. In the example, the power subsystem is further subdivided into its three major components and subdivisions of work cost accounts, represented by the arrows, are established for more refined estimating and pinpointing for control.

The NASA companion cost control concept also includes traditional planning and reporting by cost elements, as shown in figure 31–6,

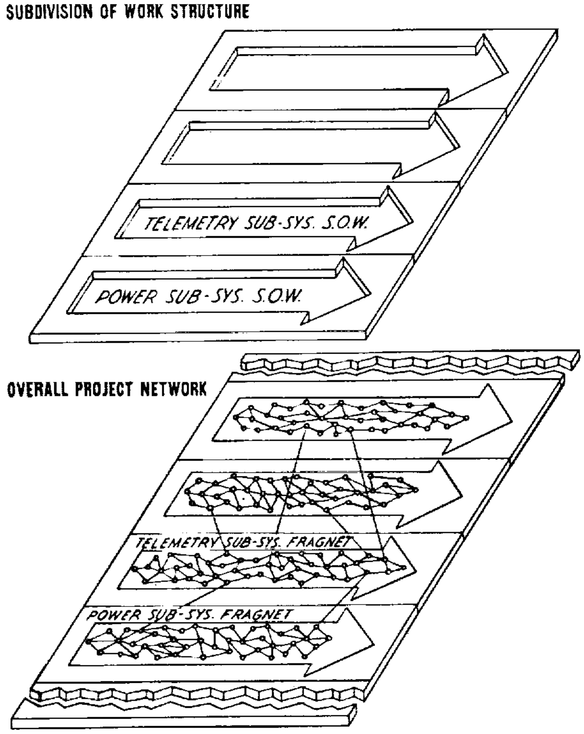

FIGURE 31–4.—Minimum acceptable time/cost correlation.

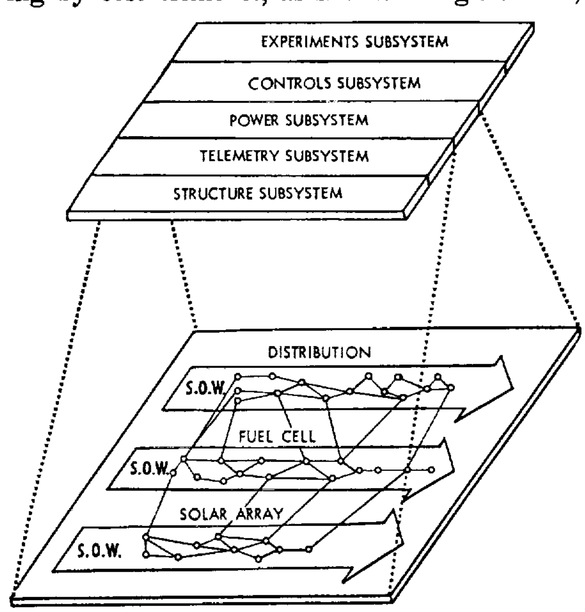

FIGURE 31–5.—Subdivision of power subsystem.

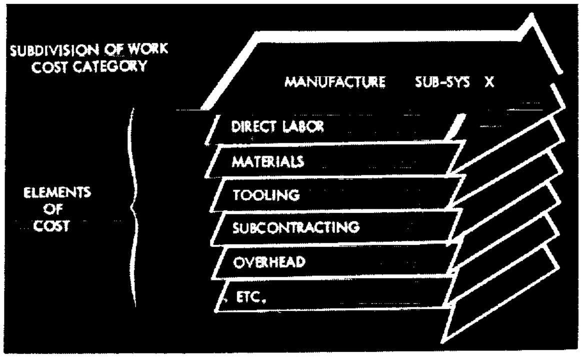

FIGURE 31-6.—Subdivision of work cost category.

either within the subdivisions of work or at a more summary level depending on a reasonable reporting level for the particular project.

Milestones and Pert are complemented by a third NASA system, adopted from industry and other Government agencies—in Line of Balance. This is primarily a tool for planning and controlling repetitive production and is therefore of limited use.

In summary, NASA's major management systems and their general application are shown in table 31-I.

Operation of these tools for more effective project management requires cooperation of NASA contractors at each step of their application and use. It is not NASA policy to require its contractors to conduct their detailed internal management in these uniform molds. The NASA systems do not go down to the level of detail required for the contractor's day-to-day operation. However, the backup detail used by the contractor to validate his reports to NASA should be easily translatable to the NASA requirements.

In the Pert Cost area a uniform approach to system design and application by contractors is desirable. To further this goal, in June 1962 NASA joined with the Department of Defense and published the "DOD and NASA Guide Pert Cost Systems Design" which describes the basic Pert Cost system concept to be used by contractors when they are required to perform in-house management on Government contracts using Pert Cost. The DOD and NASA guide, therefore, is a more detailed treatment of Pert Cost for the performing unit level. NASA Pert and Companion Cost follows the uniform system concept but is primarily directed at the higher level of total project management by the NASA project manager. Copies of the Guide may be obtained from the Superintendent of Documents, Government Printing Office, Washington 25, D.C. order number D 1.6/2:P94, at the nominal charge of $0.75 each.

TABLE 31-I.—*Major NASA Management Systems*

NASA systems	Companion Cost		
	Program Management Plan	Pert	Line of Balance
Some sample applications	Applied research Minor research and development Minor facilities Simple in-house planning Short-duration studies	Major research and development Major facilities One-time efforts Proposal evaluation Complex in-house planning	Pilot production Full production

32 Reliability and Quality Assurance Requirements

JAMES T. KOPPENHAVER

Director, Office of Reliability and Quality Assurance, Office of Programs

In programs involving the production of large numbers of hardware items which are to a great extent copies of one another, a great deal of reliance is placed upon feedback of malfunction and failure data to correct the process and thus gradually improve the product. These data are extracted in some cases during the production process and in other cases from operation or field evaluation of the end item. This procedure is reflected in the so-called "growth curves" accompanying the development and operation deployment of weapon systems.

Where human safety is involved along with production quantities, such as in the case of nuclear weapons, feedback from operational experience is somewhat limited and recourse is had to the development and practice of extremely stringent quality assurance techniques, exhaustive failure mode analysis, and use of fail-safe and redundant design schemes. In manned aircraft design, pilot and passenger safety considerations forced the same type of approach in critical areas: In all cases, strong management control of the reliability, quality, and safety operations was present.

The NASA program involves a situation in which production as normally thought of is not encountered; the program is essentially of a research and development nature but we still have to fabricate and test hardware, and the final configuration has reliability requirements not unlike those mentioned previously for reasons outlined as follows:

(1) Very high unit costs
(2) Low density of launchings—Small quantities
(3) Avoidance of flight failures—
  Impact on national prestige
(4) Flight readiness at specific periods
  Orbital and rendezvous operations
  Lunar and interplanetary travel

The cost of one first stage of the Saturn I vehicle, for example, is estimated at $20 to $30 million.

The second point is that only a few launches of any given configuration are scheduled for reasons of cost and complexity, and space operational use occurs very early in the program.

Failures are expensive in terms of dollars, lost time, and wasted manpower; also, they yield relatively little data. In view of our open policy on information concerning NASA space operations, the impact of flight failures upon our national prestige is immediately felt.

Operational readiness at specific times is an exacting requirement for space missions. For lunar and planetary operations, launch windows are restricted to relatively short periods. The exploitation of rendezvous techniques requires launch readiness at specific and limited times.

Furthermore, NASA programs must accommodate a steady stream of changes generated by increased understanding of space problems as they arise and are solved in specific missions. The spacecraft in use are single-purpose devices, few in number, and tailored specifically to each particular mission. Thus, NASA is confronted with the necessity for a completely disciplined program of design, development, fabrication, and test if we are to produce, in fact, high-quality, highly reliable hardware in an R&D program.

The NASA procures over 90 percent of its hardware from industry; in addition, because of the complexity of the system and its operational deployment at one of the national ranges, there is no instance wherein a single industrial contractor has had or is likely to have the true systems management responsibility.

In view of all these considerations, the question of procurement management as it pertains to reliability and quality is an important one and has to be very carefully planned and applied if it is to be effective. What, then, is our approach to the question of reliability and quality considerations?

First of all, the overall responsibility for the quality of procured hardware is placed on the NASA installation and in the words of our policy statement "they cannot delegate this responsibility."

Second, we have provided a written and well-defined framework for the management and implementation of quality programs jointly by the NASA installation and the contractor and we are proceeding to do the same in the reliability program area. The program requirements as they pertain both to space system contractors and to suppliers are outlined in figure 32–1. Illustrated is the scope of the quality provisions set forth in the two basic requirements documents: NPC 200–2 entitled "Quality Program Provisions for Space System Contractors" and NPC 200–3 entitled "Inspection System Provisions for Suppliers of Space Materials, Parts, Components and Services."

NPC 200–2 covers operations starting with design and development and involving purchasing, fabrication, inspection, testing, system assembly, final checkout, and operations at the launch site. NPC 200–3 sets forth requirements for an inspection system involving purchasing, fabrication, inspection, and test operations and was deliberately tailored to define minimum quality system requirements considering that small business shares our procurement dollar on both prime contracts and subcontracts.

The principal elements of the space system contractor's quality program and the associated major actions to be taken by him are shown in table 32–I. Note that the quality program in-

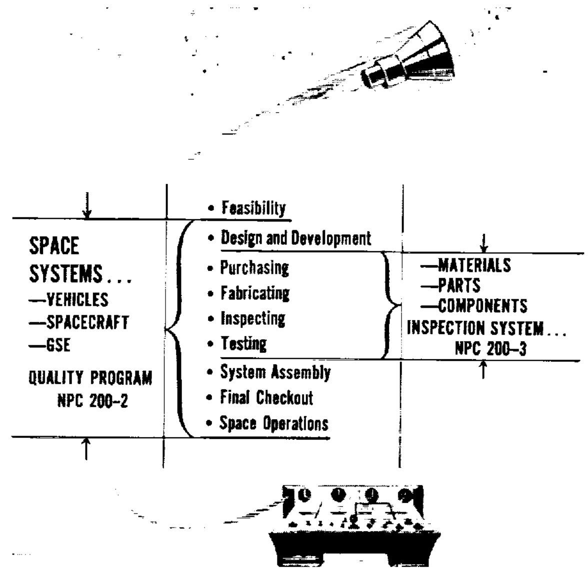

FIGURE 32–1.—Contract quality provisions.

cludes requirements which extend beyond conventional quality control. NASA's quality requirements start with the design and development concept and NASA wishes to be able to initiate all necessary and related quality actions without being denied full accomplishment because of a stated position "We don't presently do that." In fact, the orderly accumulation of space knowledge requires creativity and innovation in management and quality techniques as well as in the scientific technologies. A particular requirement of management interest is a written program plan. (See table 32–II.) The system contractor should define his quality program in detail, with special attention to quality actions at test and launch sites, since here the full facilities and management disciplines generally available at the plant are

TABLE 32–I.—*System Contractor's Quality Program*

Quality Program	Associated Action
Design and development	Plan quality program; Establish quality criteria
Purchasing	Control purchase documents; Inspect—Source/Receipt
Fabricating	Process control and inspection
Experimental items; Flight items	Qualification and conformance testing
System assembly	End-item testing
Flight operations	Data: Collection; Analysis; Feedback

diluted by the operating environment. The plan must be dynamic, unfolding as development proceeds and as specific test and inspection procedures and controls are prepared for each component, black box, and subsystem. The program plan is a key tool in identifying interface problems in the assembly of space systems and provides management with visibility into progress along the planned route to hardware quality.

TABLE 32–II.—*Quality Program Plan (NPC 200–2)*

WRITTEN PLAN FOR NASA REVIEW
FULL RANGE OF ACTIONS
PRELIMINARY PLAN
  Flow chart quality operations
  Revisions and additions to present operations
  Time schedule—documents
  Organizational structure—all program functions
DETAILED PLAN AS DEVELOPMENT PROCEEDS
  Inspection and test plan
  End item test plan—NASA approval
  Changes and additions

Inspection system requirements for suppliers direct to NASA or subcontractors to system contractor as set forth in NPC 200–3 involve the following:

(1) Written inspection plan
(2) Minimum controls, small business considered
(3) Design control not involved
(4) Records and data reporting
(5) Corrective action—defect prevention

The requirement for a written inspection plan is important; however, submission to the purchaser (who may be an NASA installation or a system prime) is required only when specified. Generally, this is determined by the critical nature of the articles involved.

A feature of particular interest which is common to both the quality program requirements just discussed and to the reliability program requirements is indicated in table 32–III.

NPC 200–2 contains broad organizational-management requirements within which the contractor assigns quality program functions to competent individuals throughout his full scope of operations. These permit the objective assessment, documentation, and reporting of true findings to be maintained throughout the contract, undiminished by engineering changes, rework, or rescheduling.

TABLE 32–III.—*Organization (NPC 200–2)*

SINGLE PATTERN NOT MANDATORY
RESPONSIBILITY AND ORGANIZATIONAL FREEDOM TO:
  Recognize and assess quality problems
  Initiate, recommend, and/or provide solutions
EFFECTIVENESS OF FUNCTION AND ABILITY OF PERSONNEL TO OBJECTIVELY ASSESS, DOCUMENT, AND REPORT TRUE FINDINGS:
  Maintained throughout contract
  Not diminished by engineering changes, rework, or rescheduling
DIRECTOR-UNIMPEDED ACCESS TO HIGHER MANAGEMENT

With respect to reliability operations which are closely associated with and a part of design and development, we are presently developing program requirements which will be applied agency-wide. (See table 32–IV.)

TABLE 32–IV.—*System contractor's reliability program*

ORGANIZATION AND MANAGEMENT
RELIABILITY ENGINEERING
  Design specifications
  Reliability prediction and estimation
  Failure mode, effect and criticality analysis
  Human engineering and maintainability
  Failure analysis
DESIGN REVIEW PROGRAM
PARTS AND MATERIALS
RELIABILITY EVALUATION
  Reliability assessment
  Integrated test program

In large programs, it is clear that the management of the reliability and the quality effort should be the function of one clearly identified group which has the task of seeing to it that all reliability and quality tasks are accomplished effectively.

Reliability Engineering refers to those operations which are an integral part of design and development but which permit explicit definition and control so that the design and development work is carried out completely.

One very important point with respect to Failure Analysis is: rapid corrective response to malfunctions throughout system development and preflight preparations is critically important. Every malfunction and, in fact, every observed peculiarity in the behavior of a system must be regarded as an important warning of potential failure and steps must

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be taken to understand the cause and eliminate all possibility of reoccurrence if we are to have successful flight programs.

For Design Review, there is a mandatory requirement to the effect that the contractor must establish and conduct a formal program of scheduled, documented design review at the system, subsystem, and major component level. NASA participation is expected and provisions for it should be made. In fast-paced programs, design review offers almost the only opportunity on a timely basis to permit the experience of individuals reflecting a wide range of interests and capabilities to be brought to bear on the problems of the individuals responsible for the design of a new system.

We have also set forth requirements relating to a detailed parts and materials program, and for a program of reliability evaluation which involves design of an integrated testing program to yield assurance that we have, in fact, the system reliability we are striving to attain.

In summary, in R&D operations, only a thoroughly disciplined design, development, fabrication, and testing program conducted jointly with the customer has any chance of yielding a consistent success record. The general requirements we have set forth are for the purpose of assisting in attaining this situation. They are not a recipe for success, however, and require joint and continuing vigilance on the part of NASA and its contractors if reliable space hardware is to be obtained in fact.

33 NASA Patent Policy and Procedure

GERALD D. O'BRIEN

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The provisions of the National Aeronautics and Space Act of 1958 which deal with patents and the implementation of these provisions by NASA are the subject of considerable controversy because they bear directly upon the issue of ownership to inventions made under Government-sponsored research. This issue of ownership to patents on such inventions has created a great deal of interest and discussion throughout the country in political and industrial circles as well as among the various agencies of the Government.

It is not the purpose of this paper to engage in this controversy or to discuss the many and diverse points of view of interested parties. These points of view generally lead to questions concerning both the value of the patent grant to our economy and to technological progress, as well as to questions concerning its consequences in the operation of a freely competitive private enterprise system; these questions, although interesting and important, are far beyond the scope of this paper. Rather, the purpose of this paper is to discuss the more mundane, but nonetheless significant, matters relating to the obligations and opportunities of an NASA contractor with respect to inventions and new technology.

Naturally, a research and development program of the scope and magnitude of that being sponsored by NASA will result in a wealth of new technology which, in and of itself, constitutes an important national resource. This resource is enriched and gains in value to the extent that it is disseminated and transferred to industrial usage. The Congress, foreseeing this, provided: (1) in section 305(b) of the Space Act, that there be included in each NASA contract effective provisions under which the contractor must furnish promptly a written report containing full and complete technical information concerning any *invention, discovery, improvement*, or *innovation* made, that is, conceived or first actually reduced to practice, under the contract; and (2) in section 203(a), for the widest practical and appropriate dissemination of this type of information.

Pursuant to this mandate, NASA, in January of 1959, issued a Property Rights in Inventions clause which was probably the longest and most complex clause ever devised for use in Government contracts. After some 3 years working experience under that clause, it is clear that compliance with its provisions left much to be desired. We can only speculate at this juncture whether the clause was so complex as to defy understanding or whether the contractors, due to a lack of incentive, were not motivated to devote the kind of attention we desire to reporting new technology. The number of inventions, innovations, improvements, and discoveries that were reported under that clause appears to fall short of what might reasonably be expected—considering the scope of research and development activities which were carried out under NASA sponsorship during that period. As recenty as December 30, 1962, NASA prescribed for use in its contracts two new clauses as a replacement for this earlier longer and more elaborate clause. Since these clauses entitled "Reporting of New Technology" and "Property Rights in Inventions" have met with mixed reaction by industry, it might be helpful to discuss certain of their salient features.

The Reporting of New Technology clause calls for reports of all inventions, discoveries, improvements, or innovations made in the performance of work under the contract whether or not the same are susceptible for protection under the U.S. patent laws. Moreover, this clause requires the contractor to conduct a continual review of the results of work performed under the contract for the purpose of identifying inventions, innovations, and other advances in the state of the art. Thus, contractors performing for NASA can no longer rely solely upon the individual initiative of technical personnel to report such technological advances. The clause calls for an active rather than a passive performance, for under this clause the contractor is required to make a positive effort to seek out and identify and report these new advances in the state of the art.

It is important that the NASA contractor realize the full scope and effect of this clause and that the reporting requirements are sufficiently broad to deal not only with inventions of a patentable nature but also with other innovations and improvements since the latter are often of value to industry and are thus of interest in the NASA Industrial Applications Program.

A great deal of research and development work, especially in system-type contracts, is done by subcontractors. Heretofore, in our experience, insufficient attention has been given to the identification of inventions and other innovations made by subcontractors. Accordingly, the contractor is required also to include these clauses in subcontracts other than supply or other routine types and to secure from such subcontractors a certification that the subcontractor has complied with this clause.

Another significant departure from the prior clause is the change in the withholding provisions to make compliance a serious monitory matter. This aspect of this clause is perhaps the most controversial. It is not the intent of NASA to place a financial burden upon its contractors, but rather to put the reporting of new technology in a frame of reference so as to receive the proper and high level attention of management.

The Property Rights in Inventions (PRI) clause deals with the rights of the Government in contractor inventions by establishing that any invention reported under and pursuant to the Reporting of New Technology clause shall be presumed to have been made under the provisions of section 305(a) of the Space Act so as to become the exclusive property of the United States. This presumption becomes conclusive unless the contractor takes the appropriate action prescribed by this clause. The purpose of the presumption as set forth in this clause is to impose the duty of proceeding with the presentation of facts upon the parties having knowledge of such facts. Finally, the RPI clause deals with the right of contractors to petition for waiver of rights to their inventions.

While the provisions of the Space Act logically and properly form the basis for the waiver to contractors of title to commercial rights in inventions, they do not do so in any specific detail. The patent provisions of the NAS Act are unique in this respect, for under this act the Congress has imposed upon the Administrator of NASA broad discretionary power and concomitant responsibility to seek out and to prescribe the circumstances which would govern the disposition of rights in inventions made under NASA contracts in a manner that will best serve the public interest. The act, in essence, provides that the Government is to own inventions made in the performance of work required under NASA contracts unless the Administrator chooses to waive the right of ownership, which he may do and will do when he feels that such action would serve the interests of the United States.

Each waiver granted by the Administrator must be subject to a royalty-free license to the Government for the practice of the invention by or on behalf of the United States or any foreign government pursuant to any agreement or treaty with the United States. Accordingly, NASA waiver policy becomes, in effect, NASA patent policy vis-a-vis contractors inventions. As indicated, the Space Act vests in the Administrator the authority and the responsibility of determining how the public interest is best served in the disposition of rights in inventions made by NASA contractors.

The act also provides for advice and assistance in these matters in that it requires that recommendations concerning proposals for waiver of rights of the United States to these inventions should be obtained from an Inventions and Contributions Board established within the Administration. In order to provide guidelines for the Board to follow in advising the Administrator in waiver cases, it was necessary to promulgate waiver regulations outlining NASA patent policy. This policy, and these regulations, should, it seems, be designed with the primary objective in mind of aiding NASA in the attainment of its mission established by the Congress for the Space Program. This is no simple matter and appears logically to require the attainment of two intermediate goals. First, the industrial community must be maintained as a sound and growing element of our economy, and second, a significant segment of that community must be encouraged to participate eagerly and without reservation in this nation's aeronautics and space program.

Since an increasing portion of the technological and scientific manpower of this nation is being devoted to space and defense-oriented technology, it is essential to a prosperous economy that opportunity be given to American industry to transfer the benefits of advances in these technologies into commercial channels. To the extent that the waiver of rights in inventions made under NASA contracts will achieve this objective such waiver of rights would appear to be in the interest of the United States. Thus, after consultation with other agencies, after public hearings, and after considerable deliberation, NASA, in October of 1959, issued its present Patent Waiver Regulations.

In these regulations inventions are grouped into two general categories: first, those inventions not generally eligible for waiver and, second, those inventions with respect to which a prima facie case for waiver may be established.

In the first class is the space-oriented type of invention. We used a technological genus here in defining the class of inventions not generally eligible for waiver because of the similarity of the Space Act to the ABC Act of 1954 which sets up a technological class of inventions with respect to which the Government should acquire the exclusive rights. As to other inventions, for which a prima facie case for waiver may be established, we included in these regulations as a class, those inventions which are usually the by-products of any research and development undertaken and which have a strong promise of commercial utility with only an incidental utility to the activities with which the Administration is particularly concerned. Other circumstances justifying the granting of waiver provided for in these regulations recognize and give due consideration to the equities of a particular contractor.

As our experience under these existing waiver regulations has grown, the conditions existing in 1959 when these regulations were first issued have considerably changed. New programs have been established by Congress in a manner officially interpreted as requiring the taking of title by the Government to contractor inventions made in these programs. Moreover, in recent months there has been an increasing evidence of an agreement within the Executive Branch to at least the fundamental policies which are desirable in this area. Accordingly, we at NASA believe revision of our present regulations to be desirable. We believe that with the benefit of many congressional and industrial studies of this subject it is now possible for NASA to adopt new criteria which would more favorably serve in the attainment of the basic objective of this agency while at the same time give adequate recognition to the patent policies and programs of other Government agencies.

Revision of present NASA regulations also seems desirable for the following reasons. First, one goal of NASA, if not the entire Government, has become to seek more active, early commercial release of the benefits of Government sponsored research and development. This goal could, it is believed, be more clearly emphasized than it is by our present regulations. Second, although the regulations currently in effect deny waiver of inventions of a particular space-oriented nature, it has become evident that emphasis should not be placed on a technological basis but rather upon considerations including the ultimate uses of inventions as they affect the consuming public, competition, or essential Government programs. Accordingly, NASA published on October 26, 1962, a proposed general revision of its present waiver regulations. Public hearings on this proposed revision were initially held on December 10, 1962, and were completed on January 28, 1963.

The material developed at the public hearings as well as the material submitted in writing is being carefully studied. All comments will be carefully considered before issuance of the proposed revision to these regulations.

The general policy of the proposed revision to these regulations is that waiver will best serve the interest of the United States when it will stimulate the application of new technology to peaceful activities and aid in the more effective utilization of scientific and engineering resources of the nation. While waiver should not be granted where the private retention of exclusive rights would be inequitable to competitors, unfair to the consuming or using public, or contrary to the interests of the public health, safety, or security, the waiving of exclusive rights to industrial contractors in other cases is favored whenever such action will foster the prompt working of the inventions or is otherwise equitable.

34 NASA Procurement System

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A large part of the NASA program, described in the preceding papers, will be accomplished by contractors. During fiscal year 1963 it is anticipated that about 90 percent of the entire NASA appropriation will be spent on contracts and this percentage may be slightly higher next year.

Each one of the NASA field centers has authority to make the contracts for projects assigned to it, subject to certain approvals by NASA Headquarters. For instance, the Marshall Space Flight Center at Huntsville, Ala., is contracting for engines and the stages of the Saturn space vehicle. The Goddard Space Flight Center at Greenbelt, Md., contracts for communication systems and weather satellites. The Jet Propulsion Laboratory at Pasadena, Calif., is operated for NASA by the California Institute of Technology under a cost-type contract and it does a substantial amount of contracting. The Procurement Office at NASA Headquarters in Washington is a staff office which formulates policies and monitors field procurement offices. It also does a limited amount of contracting where projects are controlled at Headquarters.

A booklet entitled "Selling to NASA" which lists the field procurement offices where contracts are made and gives a general description of what each buys is available to anyone. A company interested in contracting with NASA should file a Standard Form 129 at each procurement office with which it is interested in doing business. From this form the NASA procurement offices will learn the areas of work in which a company specializes.

The largest field of contracting is research and development; however, the centers buy a substantial amount of supplies, materials, and components for their in-house research work. The centers stock a wide range of items, which varies among centers, up to a maximum of 35,000 items at one center. Also, a substantial amount of construction contracting is done by NASA centers, although much of the construction work at Cape Canaveral, Huntsville, the Mississippi Test Site, and the Manned Spacecraft Center at Houston, Tex., is being accomplished for NASA by the Corps of Engineers.

The centers also contract for Architect-Engineer (A–E) services in connection with construction work. Since these are contracts for professional services and A–E firms do not compete on a price basis, a board has been set up at each center which reviews the qualifications of interested A–E firms for specific contracts and recommends to the center director a slate of at least three firms considered best qualified to perform the required services. The center director reviews the board's recommendation and selects three firms in order of preference. Negotiations are then conducted with the firm given first preference in an effort to arrive at a satisfactory contract. If a mutually satisfactory contract cannot be negotiated with this firm, negotiations are terminated and the firm notified. Negotiations are then initiated with the firm given second preference and procedures are continued until a contract has been negotiated. To encourage firms to furnish their best professional services and to enable them to render unbiased opinions, architect-engineer firms awarded a design and engineering contract for a facility will not be awarded the resulting construction contract for that facility. Architect-engineer firms interested in work at an NASA center should file a Standard Form 1071 with the center.

A substantial amount of basic research work is being done for NASA by colleges and nonprofit institutions either under grants or contracts. The Office of Grants and Research Contracts, headed by Dr. Thomas L. K. Smull, is located at NASA Headquarters and any interested educational or nonprofit institution may obtain full information about this program from that office.

How does NASA choose its contractors? Formal advertising, requesting sealed bids, and awarding a contract to the company which is the lowest bidder qualified to perform the contract is the procedure followed whenever possible. This includes the purchase of supplies and services where specifications are available and also construction. However, where the subject of the procurement is research and development, for example, spacecraft, advanced propulsion systems, or satellites, many of which have never been built before, and where there are no firm specifications so that companies are not able to bid on exactly the same item, then the procurement must be conducted by negotiation.

In research and development procurements of over $100,000, a plan for the procurement is first drawn up by the contracting officer of the center where the contract will be made. The plan includes a description of the proposed procurement, a list of all known sources, a realistic time schedule for completing each major phase of the procurement action, the recommended type of contract to be used and any special features or provisions, such as reliability requirements, which are planned to be included in the contract. In most instances, a board is appointed to evaluate the proposals submitted. In procurements of over $5 million, the plan is subject to the approval of NASA's Associate Administrator, Dr. Robert Seamans, who also appoints the source evaluation board based upon the recommendations of the appropriate center director. In procurements below $5 million the board appointments are made by the cognizant center director.

The board determines the criteria which will be used in evaluating proposals. In addition to the many technical factors relating to design, development, and test programs, the board develops a list of factors relating to business management, including project organization, manpower and facilities availability, direct and related experience, past performance, project scheduling, estimates of cost, subcontracting structure, labor relations record, and others. These criteria are included in the Request for Proposals with some indication as to their relative importance.

Usually a Preproposal Conference will be held at which time the technical and business details of the procurement will be discussed and company representatives may ask questions. The companies which will be requested to submit proposals are those which are considered to have the experience and capabilities to perform the work; however, any company which wishes to submit a proposal may do so, whether or not it was included in the original request, and the fact that a company elects not to submit a proposal will not prejudice it in future procurements. NASA thinks that it makes good sense to advise any interested company if its qualifications appear marginal for a particular job. The engineering time and expense which proposal preparation requires is substantial and can be devoted to other efforts by companies which are not in a competitive position.

After proposals are received they are given a thorough evaluation by the board. Information is obtained from other Government departments, particularly the military, as to their past experience with the companies which have submitted proposals. Oral or written discussions are held with companies submitting proposals within a competitive range, as to price and other factors. Such discussions may include oral presentations by companies. If the estimated cost of the contract is over $5 million, the board presents its findings to the Administrator of NASA, Mr. James E. Webb, the Deputy Administrator, Dr. Hugh L. Dryden, and Dr. Seamans; these three members of NASA's general management, as a group, then select the company with which negotiations will be conducted. If satisfactory terms can be negotiated, a contract will be awarded to that company.

The purpose of this procedure is to select the contractor who appears to be best qualified to perform the work successfully within the required schedule at a reasonable cost.

There are times when it is evident that one company should be selected as the contractor because it has a substantial advantage in its capability to undertake a particular development, and it would be a disservice to other companies to go through the competitive procedure. Instances in which the work to be performed is a follow-on to a prior contract or where a company has a unique capability or experience are examples of such a sole source situation. However, wherever it is possible to secure real competition, and this is usually the situation, NASA will do so, and all qualified companies will be given an equal opportunity to compete.

NASA contracts carry a priority rating which entitles contractors and subcontractors to priority in delivery of materials ahead of regular production. The Apollo project, which is the Manned Lunar Landing Program, and which includes the Saturn and Gemini elements, as well as the Centaur and soon-to-be-completed Mercury project, all carry a DX rating, the highest national priority.

The principal legal authority for NASA procurements is the same as that for the military departments, the Armed Service Procurement Act of 1947; the NASA works closely with the Department of Defense and the Army, Navy, and Air Force in many respects. Many of the contract provisions are the same as those found in defense contracts: for instance, the items of allowable costs.

The fixed-price type of contract is used whenever possible; however, in many of NASA's larger research and development procurements the engineering and production difficulties which may be encountered make it impossible to establish a fixed price. For such contracts the cost-plus-fixed-fee form is generally used.

An attempt is being made to place incentive provisions in NASA contracts which will reward contractors for superior performance and the saving of costs. The conventional way this has been done by other departments is to set cost and performance targets. If a contractor can successfully better these targets it receives an extra profit, but if the contractor fails to reach the target it loses profit, all of which is based on a formula set forth in the contract. In order to fix fair targets it is necessary to have past cost and performance information, and NASA's projects are for the most part so new that this past experience is not available. Nevertheless, we are attempting to find new ways of including incentive provisions in NASA contracts and have already had some success.

Other Government departments, particularly the military, do a certain amount of contracting for NASA where the items we need are already under development or production for their use. An example of this is the procurement of Atlas rockets. In fiscal year 1962 procurements by other agencies amounted to 21 percent of the dollars NASA spent by contract. In those instances, the contractors are chosen by the other departments and the contracts in all respects are the contracts of the other departments.

Generally, after one of the larger NASA contracts is placed, the military department which has cognizance of the contractor's plant is asked to perform certain in-plant contract administration for NASA, that is, to audit vouchers for payment, keep accountability of property records, perform inspection work, and so forth. This prevents setting up a duplicate staff to do this work and the contractor has only one system to follow. An execption to this situation is where NASA has all or substantially all the contract work in a plant, in which case, NASA will do its own contract administration work.

NASA has a Board of Contract Appeals and any disputes under the "Disputes" clause are referred to it even though one of the military departments may be administering the contract. NASA has authority to pass on mistakes in bids under formally advertised contracts. It also has a Contract Adjustment Board to consider claims filed by contractors for extraordinary relief.

Small business concerns play an important role in NASA contracting. During fiscal year 1962 small business companies received 66 percent of the total number of contractual actions, large and small, placed by NASA. This small business share of NASA procurement amounted to approximately $125 million, or 12 percent of the total NASA procurement placed with all business firms. Small companies do not have the large technical staff or extensive facilities required to perform major development contracts for spacecraft or engines, but they are able to compete successfully for many of NASA's contracts, particularly in furnishing components and supplies. During fiscal year 1962, of the hundred contractors who received the largest dollar value of NASA prime contracts, 24 were small business concerns. In those procurements where small business concerns submited bids, they were successful in receiving 57 percent of the dollar value of the awards.

Each center, as well as NASA Headquarters, has a small business specialist available to counsel small business companies on how they can participate in the NASA program. They also review purchase requests, which is the initiating document in each procurement, to be sure small business sources are solicited. Last year there were 744 procurements set aside solely for small business participation.

Perhaps the largest field for small business concerns in our program is in subcontracting. There is a provision in prime contracts of over $500,000 requiring the contractor to have a small business subcontracting program and also a "Make-or-Buy" clause which assures NASA of certain controls over the agreed amount of work prime contractors will subcontract. In order that companies which are interested in securing subcontract work may know where to solicit business at the time companies are preparing their prime contract proposals for research and development procurements estimated to cost $100,000 or more, NASA synopsizes in the Department of Commerce Business Daily a description of the proposed procurement and a list of the companies, with their addresses, which will be solicited for proposals.

The amount of money the Congress has appropriated for the NASA program has been substantially increased each year. Since most of it is being spent on contracts, we are conscious of the impact that this may have on the country's economy. To assure the greatest chance of success of the program, contracts are placed with companies which are considered best qualified to perform the work wherever they may be located. Most of these companies have specialized facilities in being which have cost many millions of dollars; to place contracts with companies which would have to duplicate this investment would be wasteful. It is NASA policy that contractors will furnish all facilities required for the performance of NASA contracts. However, in those cases where a determination is made that, due to the nature of the work involved, machinery and equipment are to be furnished by the Government, NASA utilizes such equipment as may be available from Government excess lists and the national industrial reserves.

The fact that a company receives a prime contract does not mean that all the contract money will be spent there. A substantial part of the work is subcontracted and dollars filter into many different locations. A study was made of nine companies which received a large portion of NASA dollars in 1961. These companies subcontracted approximately 50 percent of their receipts to more than 10,000 first-tier subcontractors located in 46 states. In fiscal year 1962, 40 percent of NASA contracts of over $25,000 were placed in areas which at the time of award were designated by the Department of Labor as substantial labor surplus areas.

Efforts are being made by NASA to buy directly certain items of our programs rather than have them purchased by the large prime contractors. However, this is not always practical in development of new items where numerous engineering changes will be made and the prime contractor is held responsible for the performance of the system. The break-out purchase of components and parts is more applicable after development is completed and specifications are firm. There will be very few production contracts where such specifications are available in the foreseeable future.

One of the most important aspects of procurement is the careful expenditure of funds. Particularly in research and development procurement, NASA is buying the management ability of a contractor. NASA expects that the contractor will exercise the same degree of care in the expenditure of contract funds as it would if a competitive commercial item were being produced for profit.

When a company estimates its costs in offering a proposal or quotes a fixed price, it is expected that the amounts stated are realistic of what the item will eventually cost and are not underestimated. We want it firmly understood that the contractor's original cost proposal will be a key factor in the negotiation on cost and fee in the definitized contract. Contractors are expected to use every economy that can be found in the performance of NASA contracts, and companies which can find ways of cutting costs and producing reliable end items on schedule will be favorably considered for other contracts.

The fact that a contractor estimates its costs lower than another does not mean that the ultimate cost will be less under the cost-plus-fixed-fee type of contract. A low estimate may mean that the company does not understand the extent of the work to be done. The experience a company has had in similar work, its available facilities, its management ability to hold costs to a minimum, and its careful engineering planning so that costly mistakes will not be made are things looked for in a contractor. The fee is only one element of cost to the Government. We wish to avoid cost overruns or to make expensive specification changes.

Although the NASA program is urgent and we are seeking ways to simplify the procurement process, we will not sacrifice the interest of the Government for speed in placing contracts. The use of letter contracts is avoided whenever possible. We believe that companies will find NASA fair in its contract terms, including the amount of fees or profits allowed, and we expect the same consideration from contractors. During fiscal year 1962 the average fees of NASA contracts were slightly less than 6½ percent.

Industry and research institutions are playing an increasingly important role in the NASA program. As previously indicated, more than 90 percent of the NASA budget will be spent on contracts with industry and with educational and other nonprofit institutions. Credit for the success of our country's space effort has been and will continue to be due in large measure to the productive ability of companies working with NASA.

Concluding Remarks

ROBERT C. SEAMANS, JR.
Associate Administrator

It is important that our space objectives be discussed by all of us in government and industry, in the universities, and in the scientific community in order to make wise decisions together in the years ahead. Simply stated, our goal is to become preeminent in all important aspects of space, and to conduct this space program in such a way that our scientific, technological, and operational competence in space becomes clearly evident to the world.

To be preeminent in space it is vital that we conduct scientific investigations across a broad spectrum. We must study geophysical phenomena about the earth; analyze the sun's radiation and its effect on earth; explore the moon and the planets; measure rays and magnetic fields in interplanetary space; and conduct astronomical measurements.

Preeminence in space also demands that we have an advancing technology which allows us to send increasingly larger payloads into orbit around the earth and to travel to the moon and to the planets. We must also make substantial progress in our propulsion technology. We must increase internal power capability. We must develop instruments and life support systems that will operate with full reliability for long periods in the alien and severe environment of space. We must advance the techniques of transmitting large quantities of data over vast distances. In addition, American preeminence in space calls for the ability to launch space vehicles at precisely prescribed times. It calls, too, for the capability of increasing payloads in exact orbits. We must learn the techniques of maneuvering in space; of rendezvous with other large objects in space. We must master the exacting techniques for landing on the moon and the planets, and returning to earth at increasingly high speeds.

Finally, preeminence in space means that we must learn to make, inspect, assemble, and checkout space vehicles and component parts that will operate efficiently in space not for months, but for years. Such improvements in reliability translate into safety for astronauts, scientific measurements of long duration, and in the systems of economical weather and communications satellites. Logic demands that in carrying out our space efforts we must strive to improve the competence of government research, of flight centers, of industry, and of the universities involved. Their several roles must be implemented so that they can work together harmoniously towards our common end—preeminence in space for the United States. In addition, we must coordinate our efforts with many foreign nations to track and acquire data from our spacecraft and to carry on space projects of mutual interest, utilizing satellites for weather forecasting and worldwide telecommunications.

NASA has many flight missions in various stages of preparation, each directed towards completing an important part of our national space objectives. Exploration of the moon by American astronauts serves as a focal point for a large segment of the space-flight program, since its successful accomplishment requires much of the scientific data and many of the techniques we will learn from our flight mission. Prior to landing on the moon we must obtain further information on space radiation, and we must land unmanned spacecraft on the moon to measure the surface condition. We must provide for additional tracking facilities, both land-based and ship-born. We must increase our knowledge of reentry phenomena and a host of other investigations important to technological development must be made.

As a consequence, the manned lunar program, in its entirety, is the largest single mission of NASA, constituting three-quarters of our budget and being carried out with the utmost urgency. Practically every major activity of NASA, both at headquarters and at our field centers, is involved in this effort in one way or another. The remaining one-fourth of our program is also important, however, to aeronautical and space superiority and includes our communications and meteorology program, planetary exploration, a broad research and technology effort in such areas as aeronautics, electronics, and chemical and nuclear propulsion, and a number of scientific satellite programs as, for example, the astronomical observatory, designed to advance our knowledge of the universe.

We are confident we shall succeed in establishing U.S. preeminence in space. Towards this end, we are committed to the American exploration of the moon before the end of this decade. As President Kennedy noted, it will not simply be a case of American explorers going to the moon, it will be an entire nation, for all of us must put them there and bring them back. In this context, the partnership between NASA and industry is a necessity for success in the exploration of space. Neither could go it alone in the effort to reach the moon.

It is well to remember that 90 percent of every dollar is spent with industry, either directly through contracts, or through cooperative industry-university programs. Through subcontracting, space dollars reach nearly every segment of the American economy. The exploration of space is thus a truly national effort.

Through such activity as the Second NASA-Industry Conference, we are attempting to develop a mutual understanding in which decisions can be made wisely, based on a solid foundation of relevant information.

In the preceding papers, attempts have been made to delineate information for industry to chart its own long-range plans in support of the space effort. The specific questions from industry conferees have been most helpful in pinpointing areas of interest to industry, and the NASA papers have been presented with these in mind. Black and white video tape and 16-millimeter motion picture recordings of each presentation given at the conference are available to anyone who is interested for presentation at regional meetings. We also invite consultation and questions at the appropriate NASA field centers.

APPENDIX A—BIOGRAPHIES

MILTON B. AMES, JR., is Director of Space Vehicles, Office of Advanced Research and Technology, responsible for developing coordinated programs of applied research and advanced technology to provide a rational basis for advancing the state-of-the-art of space vehicle design and operation, and to promote prompt application of new concepts and other results of such programs that offer promise of improvements in performance, efficiency, and reliability of space vehicles. Mr. Ames joined the staff at Langley in 1936, transferring to Headquarters in 1941. He has headed many areas of research, including those as Chief of the Aerodynamics Division, Chief of the Aerodynamics and Flight Mechanics Research Division, Assistant Director of Research for Aerodynamics and Flight Mechanics, and Deputy Director of the Office of Advanced Research Programs at Headquarters. He is a fellow of the American Institute of Aeronautics and Astronautics and serves as one of the U.S. representatives on the Fluid Dynamics Panel of AGARD. Mr. Ames received his B.S. degree in aeronautical engineering from Georgia Institute of Technology in 1936.

A. M. GREGG ANDRUS is Acting Chief of Communications Satellite Technology, reporting directly to the Director, Communications Systems, Office of Applications. He is primarily concerned with the planning, programing, and technical review of the supporting research and advanced technical development program on communications satellites, and with preparation and coordination of future plans and programs. Before joining NASA in February 1962, Mr. Andrus was with the Army Signal Corps, with research responsibilities in radar techniques, data processing, machine language translation, and electronic components power sources. Prior to this he did research and development on electron tube techniques and solid-state devices for the Navy Bureau of Ships. Mr. Andrus received a B.S. degree in electrical engineering from Louisiana State University in 1949, and an LL.B. degree from Georgetown University in 1957. He is a member of the Virginia State Bar and a member of the Institute of Radio Engineers.

DR. RAYMOND L. BISPLINGHOFF assumed the responsibilities of Director, Office of Advanced Research and Technology, in August 1962. He marshals the planning, direction, execution, and evaluation of all NASA research and technological programs conducted primarily to demonstrate the feasibility of advanced concepts, structures, components, or systems that may have general applications to the nation's aeronautical or space objectives. Before coming to NASA Dr. Bisplinghoff was deputy head of the Department of Aeronautical Engineering at the Massachusetts Institute of Technology. Dr. Bisplinghoff received a B.S. degree in aeronautical engineering and an M.S. degree in physics from the University of Cincinnati, and an Sc. D. degree from the Swiss Federal Institute of Technology. He is a fellow of the American Institute of Aeronautics and Astronautics, the Royal Aeronautical Society, the American Association for the Advancement of Science, and the American Academy of Arts and Sciences, and a member of Phi Eta Sigma, Tau Beta Pi, and Sigma Xi.

ERNEST W. BRACKETT was appointed Director of Procurement and Supply Division in January 1959. The functions of this division include transportation and logistic planning. Prior to coming to NASA, Mr. Brackett was a Contract Specialist to the Director of Procurement and Production at the USAF Air Material Command Headquarters. A graduate of Cornell University, he received a bachelor of arts degree in 1925, and practiced law until 1942. After World War II he joined the Department of the Air Force as Chief of the Contracts Branch in the Procurement Division, transferring to the Air Material Command in 1950. He is a member of the New York State and District of Columbia Bars and has been admitted to practice before the U.S. Supreme Court.

EDGAR M. CORTRIGHT, Deputy Director of the Office of Space Sciences, shares responsibility with the Director, Dr. Homer E. Newell, in planning and directing all NASA programs for the unmanned scientific exploration of space including probes, geophysical and astronomical satellites and probes, biosciences, and development and use of light- and medium-class launch vehicles. Prior to this assignment, Mr. Cortright was Assistant Director for Lunar and Planetary Programs. Before heading that post, he was Chief, Advanced Technology Programs, in the Office of Advanced Technology where he was directing initial formulation of the meteorological satellite programs, Tiros and Nimbus. Mr. Cortright earned his B.S. and M.S. degrees in aeronautical engineering at Rensselaer Polytechnic Institute in 1947 and 1949, respectively. He joined the NASA Lewis Research Center in 1948 where he was Chief of the 8 x 6-foot Supersonic Wind Tunnel Branch and later Chief of the Plasma Physics Branch after attending Nuclear Reactor Training School at Lewis. He is an associate fellow of the American Institute of Aeronautics and Astronautics.

MELVIN S. DAY was appointed Director, Office of Scientific and Technical Information, in 1962. He directs the overall NASA scientific and technical information program, including its publishing, referencing, and bibliographic activities. He joined NASA in 1960 as Deputy Director, Office of Technical Information and Education Programs, representing NASA on Government interagency committees and international panels and boards. Prior to this he had served with the Technical Information Service of the U.S. Atomic Energy Commission in Oak Ridge and Washington, D.C. He was Director when he left to come with NASA. Mr. Day is a member of the American Chemical Society, American Nuclear Society, American Association for Advancement of Science, American Institute of Aeronautics and Astronautics, American Documentation Institute, and Special Libraries Association. He received a B.S. degree in chemistry from Bates College in 1943. He is currently serving on the Technical Information and Documentation Committee of AGARD–NATO.

DR. HUGH L. DRYDEN has been Deputy Administrator of NASA since its creation by the Congress in 1958. Prior to this he was Director of NACA for 9 years until it was superseded by NASA. Dr. Dryden is internationally recognized for his contributions to fluid mechanics and boundary layer phenomena, and has been highly honored for his leadership in research and development associated with aeronautics and astronautics. He holds a number of posts in addition to his NASA responsibility; among these: Alternate Representative of the United States to the United Nations Ad Hoc Committee on the Peaceful Uses of Outer Space; advisor to the Science Advisory Committee to the President; and national delegate to the NATO Advisory Group for Aeronautical Research and Development. Many honors and awards have come to Dr. Dryden including the second highest U.S. award, the Presidential Certificate of Merit. Dr. Dryden is home secretary of the National Academy of Sciences; honorary fellow and former president of the American Institute of Aeronautics and Astronautics; honorary fellow of the Royal Aeronautical Society and the British Interplanetary Society; fellow of the American Academy of Arts and Sciences; correspondant de l'Academie des Sciences de l'Institute de France; and a member of numerous professional societies and organizations. He is a trustee of the National Geographic Society.

HAROLD B. FINGER, appointed Director of Nuclear Systems, Office of Advanced Research and Technology in November 1961, manages all aspects of NASA's research and development program on nuclear electric power systems and electric propulsion, as well as the flight testing of these electric systems and of nuclear rocket systems. Mr. Finger is also Manager of the joint AEC–NASA Space Nuclear Propulsion Office, and in this capacity is responsible for all aspects of the development of nuclear rocket propulsion. He received this appointment in August 1960. Mr. Finger joined the Lewis Research Center staff in 1944 where he progressively assumed the responsibilities of Head of the Axial Flow Compressor Section, Associate Chief of the Compressor Research Branch, and Head of the Nuclear Radiation Shielding Group. He has specialized in research in the fields of turbomachinery, nuclear rockets, and shielding. A member of the American Institute of Aeronautics and Astronautics, he earned a bachelor's degree in mechanical engineering from City College of New York in 1944, and an M.S. degree in aeronautical engineering from Case Institute of Technology in 1950.

D. BRAINERD HOLMES was appointed Director of the Office of Manned Space Flight in November 1961 and is responsible for direct program supervision of the manned space flight activities at NASA centers and in industry. This includes Projects Mercury, Gemini, and Apollo. Mr. Holmes is also Deputy Associate Administrator, in charge of institutional and operational matters at the field centers directly involved in the manned space flight program. Prior to joining NASA, he was general manager of RCA's Major Defense Systems Division, where he provided technical direction and management of advanced military electronic systems in the fields of detection and warning. He also served as the Ballistic Missile Early Warning System Project Manager for RCA, the weapons system contractor, and was responsible for coordinating for the Air Force a vast effort involving the Government and some 2,900 companies. Mr. Holmes was with Western Electric Co. and Bell Telephone Laboratories between 1945 and 1953 where he initiated and developed the first precision recording transmission measuring set and other test equipment for the black and white television coaxial system.

THOMAS E. JENKINS, Director, Management Reports, Office of Programs, joined NASA's Goddard Space Flight Center as Administrative Officer in 1958, transferring to Headquarters in 1959 as Program Management Officer in the Office of Space Flight Programs. The following year he was appointed Assistant Director for Management Reports and later to his present position, where he is responsible for development implementation and operation of program management and reporting systems for NASA and its contractors. Before joining NASA Mr. Jenkins held several positions with the U.S. Naval Research Laboratory, including those of Deputy Comptroller, Budget Office, and Business Manager of Project Vanguard. He is a 1947 graduate of the University of California, Berkeley, with an A.B. degree, and is a member of the Society for the Advancement of Management.

DR. ALBERT J. KELLEY, as Director of Electronics and Control, Office of Advanced Research and Technology, is responsible for management and direction of NASA advanced research and development in the fields of guidance, flight control, communications, and data processing. A 1945 graduate of the U.S. Naval Academy with a B.S. degree, he earned a B.S. degree in electrical engineering in 1948 and the Sc. D. degree in 1956 at the Massachusetts Institute of Technology. Dr. Kelley joined the NASA staff in March 1960 as Agena Launch Vehicle Program manager. A former Navy experimental test pilot and Eagle Missile System Project Officer, Dr. Kelley has specialized in the fields of guidance and control of missiles and space vehicles, and experimental flight test. He is a member of Sigma Xi, Tau Beta Pi, Eta Kappa Nu, Sigma Gamma Tau, and the American Institute of Aeronautics and Astronautics.

DR. EUGENE B. KONECCI was appointed Director of Biotechnology and Human Research, Office of Advanced Research and Technology, in June 1962. Before joining NASA, he was Chief of the Life Sciences Section, Missiles and Space Systems Division, Douglas Aircraft Co. Dr. Konecci is responsible for directing research and technology leading to development of future life support systems, advanced systems to protect man in the space environment, determination of how man can be best utilized in space flight missions, and the research required to assure man's performance capabilities in space. Dr. Konecci attended Clemson College, Roosevelt University, University of Chicago, and the University of Berne. His bachelor degrees are in biology and chemistry. He was awarded a doctorate in medical physiology from the University of Berne. He was Research Scientist at the Air Force School of Aviation Medicine and was Chief of the Physiology and Toxicology Branch of the Directorate of Flight Safety, Inspector General Office, before joining the Douglas Co. in 1957.

JAMES T. KOPPENHAVER is Director, Office of Reliability and Quality Assurance, and is responsible for staff direction and guidance of the NASA-wide reliability and quality assurance program. In addition, his office manages Headquarters reliability study and assessment contracts with industry. He reports to the Director, Office of Programs. Previous to his appointment as Director in April 1962 he was Deputy Director and Chief, Systems Engineering of this office. Mr. Koppenhaver received a B.S. degree from Muhlenberg College in 1946 and a master of letters degree in physics from the University of Pittsburgh in 1951. Before joining NASA, he held positions with RCA, Office of Ordnance Research, and Filtron Co.

DR. HERMANN H. KURZWEG, Director of Research, Office of Advanced Research and Technology, is primarily concerned with five specific programs in advanced research—aerodynamics, fluid mechanics, environmental physics, mechanics of flight, and data acquisition and transmission. Dr. Kurzweg received his Ph. D. degree from the University of Leipzig in 1933. During World War II, he was chief of the Research Division and deputy director of the Aerodynamic Laboratories at Peenemuende. His work there included aerodynamic research on the V–2 rocket, the antiaircraft rocket "Wasser Fall", and the design of the first 40-by-40 centimeter supersonic wind tunnel. In 1946 he came to the United States to work at the Naval Ordnance Laboratory. There in 1956, he became Associate Technical Director. Dr. Kurzweg was appointed to his current position with NASA in September 1960. He is a member of the advisory panel on aeronautics for the Office of the Assistant Secretary of Defense (R&E), the Fluid Dynamic Panel of NATO's AGARD, and is a fellow of the American Institute of Aeronautics and Astronautics.

WILLIAM E. LILLY, as Director of Program Review and Resources Management, Office of Manned Space Flight, is responsible for providing the total financial, administrative, and business management support and services for that office. In addition, he is responsible for administration and direction of approved facility projects in support of the Manned Space Flight Program. A graduate of the University of California, Berkeley, with an A.B. degree in political science, Mr. Lilly is a member of Phi Beta Kappa and Pi Sigma Alpha. Prior to his present assignment, he was Chief of Plans and Programs Coordination in NASA's Office of Launch Vehicles Programs. Before joining NASA in 1960, he was Assistant to the Director, Plans and Programs, for the Navy's Special Projects Office, and has served as Deputy Budget Officer of the National Bureau of Standards, and with the Navy's Bureau of Ordnance and Ordnance Test Station in Budget and Program Analyst capacities.

WALTER L. LINGLE, JR. was appointed NASA's Assistant Administrator for Management Development in August 1962. Mr. Lingle is responsible for the review and development of recommendations on major management problems. Formerly executive vice president of Procter and Gamble, and associated with that firm from 1931 until 1962, Mr. Lingle has been manager of the firm's foreign business since 1945, and was elected vice president in charge of oversea operations in 1948. He also had been in charge of the cellulose and oil mills since 1945 and in 1957 assumed responsibility for Procter and Gamble's toilet goods and paper products divisions. Since March 1962, he had served as Deputy Administrator of the Agency for International Development. He is a graduate of Davidson College, N.C.

GEORGE M. LOW was appointed Director of Spacecraft and Flight Missions, Office of Manned Space Flight, in November 1961. He is responsible for the development of manned spacecraft and for the management of manned space flight mission operations including Projects Mercury, Gemini, and Apollo. An aeronautical engineer, Mr. Low earned his bachelor's degree in 1948 and his M.S. degree in 1950 from Rensselaer Polytechnic Institute. He joined the NASA staff at Lewis Research Center in 1949 where he specialized in research in the fields of aerodynamic heating, boundary layer theory and transition, and internal flow in super- and hypersonic aircraft. In 1958 he transferred to Headquarters as Chief of Manned Space Flight, and later was named Assistant Director for Manned Space Flight Programs. Mr. Low is an associate fellow of the American Institute of Aeronautics and Astronautics and the recipient of NASA's Outstanding Leadership Award.

DR. RICHARD B. MORRISON was appointed Director, Launch Vehicles and Propulsion Programs, in the Office of Space Sciences in June 1962. Prior to this, he had been associated with the University of Michigan's Department of Aeronautical Engineering since 1946. He took a leave of absence in 1957–58 to serve as technical test director for Ramo-Wooldridge Corp. at Cape Canaveral, Fla. He earned B.S. and M.S. degrees in aeronautical engineering at Massachusetts Institute of Technology and received his Ph. D. at the University of Michigan in 1952. During World War II, he served in the Navy as an engineering training officer and an instructor in aerodynamics and engines. Dr. Morrison was chairman of the Space Sciences Committee of the University's Institute of Science and Technologies. He was awarded the America Rocket Society's Michigan Astronautics Award in 1962 for outstanding contributions to astronautics.

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BOYD C. MYERS II is responsible, as Director of Program Review and Resources Management for the Office of Advanced Research and Technology, for establishing and managing program approval and review systems, providing a centralized resources management operation, assuring the validity of program plans, processing research and technical reports, and performing liaison activities for the NASA Research Advisory Committees. Before assuming these responsibilities in November 1961, he was Technical Assistant to the Director, Office of Advanced Research Programs. An aeronautical engineer with a B.S. degree from Virginia Polytechnic Institute in 1946, Mr. Myers joined the staff at Langley Research Center in 1947, where he conducted research on stability and control characteristics of swept wings. Transferring to Headquarters in 1950, he directed research in aircraft operation problems, icing, meteorology, flight safety, and human factors. Mr. Myers is a member of the American Institute of Aeronautics and Astronautics.

DR. JOHN E. NAUGLE, as Director of Geophysics and Astronomy Programs, Office of Space Sciences, is responsible for planning and direction of NASA's geophysics and astronomy programs, using satellites and sounding rockets to explore the earth's environment, for studies of the sun and its effect on the solar system, and for astronomical observations. Dr. Naugle is a graduate of the University of Minnesota, receiving a bachelor of physics degree in 1949, M.S. degree in 1950, and Ph. D. degree in 1953. Specializing in cosmic ray and upper atmosphere research, he has taught at the University of Minnesota, been Senior Staff Scientist at Convair Scientific Research Laboratory, Head of Nuclear Emulsion Section at Goddard Space Flight Center, and Head, Energetic Particles Program, Satellite and Sounding Rocket Programs, Office of Space Flight Programs, NASA, prior to his present assignment. He is a member of Sigma Xi, American Physical Society, and American Institute of Aeronautics and Astronautics.

ORAN W. NICKS, Director, Lunar and Planetary Programs, Office of Space Sciences, is responsible for the overall Headquarters program management of lunar and planetary programs, including program planning and development and maintaining cognizance of essential technological advancements. He is concerned directly with program execution by JPL and other NASA centers, in addition to overall coordination between NASA, industry, and other Government agencies. Mr. Nicks came to NASA as Head of Lunar Flight Systems, Office of Lunar and Planetary Programs, in March 1960 from the Vought Astronautics Division of Chance-Vought Aircraft, Inc. There he had served as project engineer for advanced space systems concepts, and was Scout project engineer from concept-to-hardware. Prior to this he worked with North American Aviation, Inc., where, among other assignments, he was project engineer of missile design study. He is a member of the American Institute of Aeronautics and Astronautics and the American Astronautical Society. In 1943 he received an A.A. degree in aeronautical engineering from Spartan College, and in 1948 his B.S. in mechanical engineering from the University of Oklahoma.

JOHN D. NICOLAIDES is Director of Program Review and Resources Management, Office of Space Sciences. Prior to joining the headquarters staff in December 1961, he was Technical Director for the Navy Astronautics Program in the Bureau of Naval Weapons, where he was responsible for such programs as Transit, Anna, and Caleb, among others. Before this he served as Chief Exterior Ballistician and later the Assistant for Aerodynamics, Hydrodynamics, and Ballistics in the Navy's Bureau of Ordnance. Mr. Nicolaides was graduated from Lehigh University in 1943 with a B.A. degree in aeronautics, received an M.S. degree in engineering from Johns Hopkins University in 1953, and his Ph. D. degree from Catholic University is pending. He is an associate fellow of the American Institute of Aeronautics and Astronautics.

GERALD D. O'BRIEN was named Assistant General Counsel for Patent Matters in December 1958. He was formerly Patent Counsel of the Navy Department's Bureau of Ordnance, a post which he held for 12 years. After 4 years at the U.S. Naval Academy, Mr. O'Brien entered George Washington University, where he was awarded a B.S. degree in electrical engineering in 1937. He received an LL.B. degree from American University's Washington College of Law in 1940, and a master of patent laws degree from the National University School of Law in 1950. Mr. O'Brien has been on the faculty of the Washington School of Law since 1951, and is a member of the American Patent Law Association, the District of Columbia Bar, and the Patent Lawyers' Club of Washington, D.C.

CARL B. PALMER is Chief, Sponsored Research, Office of Research Grants and Contracts. His responsibilities lie principally in the areas of policies and procedures relating to unsolicited research proposals and support of research in educational and nonprofit scientific institutions. Mr. Palmer received his B.A. degree in physics at Miami University in 1940, and his M.A. degree at the University of Minnesota in 1942. He joined the Langley staff in 1942, where he worked in thermodynamics and fluid mechanics, and in the design and early operation of a ballistic-type transonic and supersonic research facility. Transferring to Headquarters in 1949, Mr. Palmer administered scientific and engineering research programs, primarily in educational institutions, sponsored through research grants and contracts. He is a member of Phi Beta Kappa, Sigma Pi Sigma, the American Institute of Aeronautics and Astronautics, and the American Association for the Advancement of Science.

DR. ORR E. REYNOLDS accepted the position of Director of Bioscience Programs in NASA's Office of Space Sciences in February 1962. In this capacity he is responsible for the program areas of exobiology, environmental biology, physical biology, and behavioral biology. Before coming to NASA, Dr. Reynolds served in the Department of Defense as Director of Science, Office of the Assistant Secretary of Defense (Research & Engineering), and had formerly been Director of the Biological Sciences Division with the Office of Naval Research. Dr. Reynolds received his B.S. degree in 1941 and his M.S. and Ph. D. degrees in 1943 from the University of Maryland.

MILTON W. ROSEN is Director of Launch Vehicles and Propulsion, Office of Manned Space Flight. Previously Deputy Director of Launch Vehicle Programs, he was appointed to his present position in November 1961. Mr. Rosen earned his B.S. degree in electrical engineering at the University of Pennsylvania in 1937. He joined the staff of the Naval Research Laboratory in 1940 where he worked on guidance systems for missiles. He was in charge of the Viking rocket development and was technical director of Project Vanguard before joining the NASA Headquarters staff in 1958. Specializing in research in the fields of electronics, guidance, and rocket propulsion, Mr. Rosen won the James H. Wyld Memorial Award for his work in the application of power. He is a fellow of the American Institute of Aeronautics and Astronautics and a former director of the American Rocket Society.

DR. ROBERT C. SEAMANS, JR. was appointed Associate Administrator of NASA in September 1960. In this position, he is responsible for the general management of NASA's operations which include laboratories, research centers, rocket testing and launching facilities, and a world network of tracking stations. Previous to joining NASA, Dr. Seamans was chief engineer of RCA's Missile Electronics and Controls Division. A graduate of Harvard with a bachelor of science degree in 1939, he earned an M.S. degree in 1942 and a doctor's degree in 1951 from the Massachusetts Institute of Technology. Dr. Seamans has been active in the fields of missiles and aeronautics since 1941. He held teaching and project-management positions at M.I.T., including associate professor of the Department of Aeronautical Engineering, chief engineer of Project Meteor, and director of the Flight Control Laboratory. Dr. Seamans is a member of Sigma Xi, the American Institute of Aeronautics and Astronautics, the Institute of Radio Engineers, and the American Ordnance Association. He received the Naval Ordnance Development Award in 1945 and the Lawrence Sperry Award in 1951.

DR. JOSEPH F. SHEA was appointed Deputy Director for Systems of the Office of Manned Space Flight in January 1962. He is in charge of the entire systems engineering effort for the manned space flight program. Before joining NASA, Dr. Shea was Space Program Director of the Space Technology Laboratories. He earned his B.S. degree in mathematics in 1949, M.S. degree in engineering mechanics in 1950, and Ph. D. degree in engineering mechanics in 1955 from the University of Michigan. Dr. Shea's earlier association was with the A.C. Spark Plug Division of General Motors where he served as Director of the Advanced System Research and Development Division and Manager of the Titan Inertial Guidance Program. Prior to that he was employed by Bell Telephone Laboratories as military development engineer. He is a member of the American Institute of Aeronautics and Astronautics, the Society of Mechanical Engineers, and the Institute of Radio Engineers.

ALBERT F. SIEPERT has been Director of Administration since NASA was established in 1958. He directs the development and supervision of NASA's administrative management systems, such as financial management, procurement, and personnel administration. During the previous 11 years he was executive officer of the National Institutes of Health. Mr. Siepert received the Arthur Flemming Award in 1950 for his contribution to the major reorganization and expansion of the NIH. In 1955 he received the Department of Health, Education, and Welfare's Distinguished Service Award for his administrative leadership. A graduate of Bradley University, Mr. Siepert received his bachelor of arts degree in 1936.

JOHN L. SLOOP was appointed Director of Propulsion and Power Generation, Office of Advanced Research and Technology, in February 1962. He plans, directs and coordinates the NASA programs of research studies and developments in the general area of propulsion and power generation systems as applied to solid- and liquid-fueled rocket engines and other propulsion systems, except nuclear. Previously, he had served as Deputy Director of Launch Vehicles and Propulsion in the Office of Space Sciences and from April of 1960 as Technical Assistant to the Director, Office of Space Flight Programs. Prior to this time he was Chief of the Rocket Engines Branch at the NASA Lewis Research Center. At Lewis he and his group did work on hydrogen-oxygen and hydrogen-fluorine propellants. Mr. Sloop is a fellow of the American Institute of Aeronautics and Astronautics and a former member of the board of directors, American Rocket Society.

MORTON J. STOLLER was designated Director of the Office of Applications in March 1962. He is responsible for the development and application of meteorological and communications satellites systems and for recognition and development of areas of future applications for space and aeronautical technology. Before his present assignment Mr. Stoller was Assistant Director for Satellite and Sounding Rocket Programs in the Office of Space Flight Programs, and was responsible for scientific investigations in near space, using satellites, probes, and sounding rockets. He received the degree of bachelor of electrical engineering from the College of the City of New York in 1938 and was awarded a masters degree in electrical engineering from the University of Virginia in 1952. Mr. Stoller joined the staff at Langley Research Center in 1939, where, among many assignments, he developed telemetry systems, instrumentation, and analog and digital computing machinery.

GERALD M. TRUSZYNSKI is Deputy Director of the Office of Tracking and Data Acquisition at NASA Headquarters. This office has the responsibility of providing the ground tracking and data acquisition facilities and networks for the support of all NASA space flight programs. Prior to his transferring to Headquarters in 1960, Mr. Truszynski was Chief of Instrumentation Division for NASA's Flight Research Center, where he was responsible for the development and operation of all internal on-board research instrumentation, telemetry systems, ground radar and tracking systems, and initial data reduction and computing systems required in support of tests conducted on the X-1, X-2, X-3, D-558, X-5, and X-15 research aircraft. He is a member of Tau Beta Pi and the Instrument Society of America.

JAMES E. WEBB was appointed by President Kennedy as Administrator of NASA in February 1961. He is also a member of the Federal Council for Science and Technology, the President's Committee on Equal Opportunity, the National Aeronautics and Space Council, and is Chairman of the Distinguished Civilian Service Awards Board. An attorney and businessman, Mr. Webb has been active in aviation and education. He is a former Director of the Bureau of the Budget and a former Under Secretary of State. He has been a vice president of Sperry Gyroscope Co., chairman of the board of directors of the Republic Supply Co., a director of Kerr-McGee Oil Industries, and a director of the McDonnell Aircraft Co. Mr. Webb holds a B.S. degree in education from the University of North Carolina, and numerous honorary degrees. He studied law at George Washington University and was admitted to the District of Columbia Bar in 1936.

DR. WILLIAM K. WIDGER, JR., as Chief, Operational Meteorological Satellites, Office of Applications, serves as Headquarters project officer for the Tiros and Nimbus satellites and has Headquarters responsibility for NASA's role in the operational meteorological satellite program. Before taking this post in 1962, Dr. Widger had been Assistant Chief, Meteorology Program, Satellite and Sounding Rocket Programs for NASA. Prior to joining NASA in 1960, he had been associated with the Geophysics Research Directorate of the Air Force Cambridge Research Center for 9 years, where, as Chief, Satellite Meteorology Branch, he managed the USAF participation in the origination, organization, and conduct of the Tiros project. Dr. Widger earned a B.S. degree in chemistry in 1942 at the University of New Hampshire, and the Sc. D. degree in meteorology in 1949 at Massachusetts Institute of Technology. He is a member of the American Meteorological Society, American Geophysical Union, American Association for the Advancement of Science, Sigma Xi, RESA, and Alpha Chi Sigma.

DEMARQUIS D. WYATT was appointed Director, Office of Programs, in November 1961. Previously he was Assistant Director, Program Planning and Coordination. Mr. Wyatt earned his B.S. degree in mechanical engineering at the Missouri School of Mines and Metallurgy. He joined the NACA, predecessor of NASA, at the Lewis Laboratory, where he specialized in supersonic propulsion research, and ultimately was named Associate Chief of the Propulsion Aerodynamics Division. He was transferred to NACA headquarters in Washington, D.C., in 1958. Mr. Wyatt is a member of the American Institute of Aeronautics and Astronautics.

CHARLES H. ZIMMERMAN was appointed Director of Aeronautical Research, Office of Advanced Research and Technology, in June 1962. Prior to this he was associate chief of the Aerospace Mechanics Division at Langley Research Center, where he began his career in 1929. He has become an international authority in the field of VTOL–STOL research and development, and is responsible for all such work being conducted at Langley. His original research led to the development of the "flying platform." Mr. Zimmerman is currently responsible for general and basic research in problems of aerodynamics, structures, operational problems, materials and propulsion for aircraft. Mr. Zimmerman received a B.S. degree in electrical engineering in 1929 from the University of Kansas, and an M.S. degree from the University of Virginia in 1954. He is a fellow of the American Institute of Aeronautics and Astronautics and of the British Interplanetary Society, and a member of the American Helicopter Society and the Society of Automotive Engineers. In 1956 he received the Alexander Klemin Award and the Wright Brothers Medal.

APPENDIX B—QUESTIONS AND ANSWERS

NASA ORGANIZATION

QUESTION: What are the responsibilities of each NASA installation?

ANSWER: Lewis Research Center, Cleveland, maintains technical management of NASA contracts on electric propulsion, nuclear and solar turboelectric space power systems, and liquid hydrogen rocket technology. Lewis also has project management responsibility for the M–1 engine, Centaur launch vehicle and Agena Procurement. The Plum Brook Station, Sandusky, Ohio, on land formerly occupied by the Army's Plum Brook Ordnance Works, houses the research reactor for nuclear studies done at Lewis.

Langley Rearch Center, Virginia, conducts scientific investigations on a broad scale in the areas of vehicle configurations, materials and structures, and the mechanics of flight; and concentrates on the problems of space travel and reentry, application of new materials, and supersonic and hypersonic flight.

The joint AEC–NASA Space Nuclear Propulsion Office (SNPO), Germantown, Maryland, was originated to assure the formulation and execution of an integrated development program for nuclear rockets. Cleveland's SNPO, Nevada's SNPO and the Nuclear Research Development Station at the Nevada Test Site report to this office.

Major programs at Flight Research Center, Edwards, California, are aeronautics projects, in which the problems of the X–15, supersonic transport, paraglider, and hypersonic cruise are investigated; and space vehicle systems projects, in which the flight behavior of advanced reentry vehicles such as lifting bodies is studied.

The Goddard Space Flight Center, Greenbelt, Maryland, is assigned the prime responsibility for the management of applications satellite projects, unmanned scientific satellite projects, sounding rockets, and worldwide NASA tracking and data acquisition operations.

Primary emphasis of the Jet Propulsion Laboratory, California Institute of Technology, Pasadena, is on the lunar, planetary, and deep space unmanned scientific missions. The Lab also engages in research and development on tracking and data acquisition and is responsible for the management of the deep space network.

The mission of the Ames Research Center, Moffet Field, California, includes research in the physical sciences, space sciences, and life sciences in addition to the project management of the Pioneer and Biosatellite projects.

The Manned Spacecraft Center, Houston, has as its primary mission the development of spacecraft for manned space flight programs and the conduct of manned flight operations.

The primary mission of the Marshall Space Flight Center, Huntsville, Alabama, is to develop and provide large launch vehicle and space transportation systems to meet the manned space flight program requirements. Other activities include basic research, product improvement, and the advancement of launch vehicle technology, particularly in the areas of multiengine and multistage vehicles, and nuclear and electrical propulsion.

Responsibilities of Launch Operations Center, Cocoa Beach, Florida, and of Pacific Launch Operations Office, Point Arguello, California, are to provide a central point of contact with the Missile Ranges for NASA and to give support in general, technical, administrative, and facilities areas.

The mission of Wallops Station, Wallops Island, Virginia, is to conduct nonorbital and orbital experiments with rocket-propelled vehicles carrying payloads used for aeronautical, meteorological, and space research.

The Western Operations Office, Santa Monica, California, represents NASA in the area west of Denver to support technical and contractual requirements placed on the Office by NASA Program Offices and Centers.

The North Eastern Office, Cambridge, Massachusetts, was established to provide both overall liaison with industry and the scientific, educational, and civic organizations in the northeastern region, and technical and administrative assistance in support of NASA programs within the region as requested by Headquarters or NASA Centers.

QUESTION: What is the background and function of the proposed Electronic Research Center to be located in Boston?

ANSWER: As a result of its review and study on the implementation of its electronics responsibilities for future space missions, the NASA in its FY 64 Budget is requesting Congressional approval for initial funding of $5,000,000 to establish a new Electronics Research Center to be located in the Greater Boston Area. Our long range plans call for an installation buildup over a period of six to seven years yielding a staff of 2,100, of whom 600 to 700 would be professionals, and a plant value of approximately $5,000,000.

The Center will have the function of conducting and directing research and component technique investigations in the related fields of communications, data processing, guidance, instrumentation, and control. Primarily the Center will serve as a directive group with the policy of contracting out a high proportion of its electronic research. It will be staffed and equipped to perform original work, but, generally, the staff will work with industries and universities sharing common interests.

NASA plans to perform only enough electronics research to give the staff competence to manage and coordinate a broad electronics research and development program. For example, component test facilities will be provided for evaluation of industrially developed experimental components. Most important, it will provide a regenerative path for the early exploitation of advanced techniques or developments for space flight, whatever their source.

The rate of Center growth will be gradual and represents an investment in the future of space flight, analogous to the investment made in the older Research Centers many years ago which is paying off so handsomely today. This rate of growth together with up-grading of Center personnel by continued graduate education after they are on-board is expected to allow us to meet our staffing requirements with little or no impact on scientific and engineering manpower as projected during this growth period.

The NASA considered many potential sites throughout the country for location of the Electronics Research Center. On balance, the overall university-industrial strength and capability in electronics and guidance *research* in the Greater Boston Area resulted in its selection as the location for the Center. This area, noted for its past and current heavy concentration on electronics research, both in industry and universities, provides a compatible, stimulating environment for growth of NASA capabilities in this important area of technology.

The Electronics Research Center is expected to provide capability in electronics advanced research and technology in quality and quantity to meet NASA future space requirements, since it will serve to upgrade the NASA competency in this area from its present level to that which it requires for future programs. Efforts at the Electronics Research Center will be in addition and complementary to similar work being performed at existing research centers. It is not expected that current efforts at existing Field Centers will be affected.

QUESTION: How will the new Electronics Center be adapted to the procedures of tracking and data acquisition?

ANSWER: The new Electronics Research Center will be concerned with advanced research aspects of tracking and data acquisition as opposed to near-future system requirements which are the responsibility of the Office of Tracking and Data Acquisition, NASA Headquarters, and its two primary cognizant centers, namely, Goddard Space Flight Center and the Jet Propulsion Laboratory.

QUESTION: Is there any central agency for review and coordination of various specifications for similar electronic components?

ANSWER: Responsibility for coordination of procurement specifications for electronic component parts has been assumed by the Office of Reliability and Quality Assurance, NASA Headquarters working with the various NASA installations. Questions concerning particular problems arising in this connection should be referred to that office.

QUESTION: Is there a specific NASA division to handle mechanical, hydraulic electric, and/or turbine components?

ANSWER: No.

QUESTION: What is the best central source of information to contact to carry out technical discussions in any specialized area which would give a general overall picture of the total NASA effort in such specialized areas?

ANSWER: Generally speaking the Industry Assistance Officer at Headquarters or any NASA Center is the best place to start. You will receive full support in your efforts to determine the specific individual to contact. The Technical Coordination Section of the Office of Grants and Research Contracts is the starting point for questions relating to research problems

QUESTION: What is your estimate of the number of technical people required for the expansion in NASA programs for the next fiscal year?

ANSWER: By the end of fiscal year 1964 NASA is projected to have a total complement of 32,500 including an estimated 12,250 technical (ie.. scientific and engineering) personnel. This represents an increase of 1,485 scientists and engineers from the expected total as of the end of fiscal year 1963.

QUESTION: What is being done to coordinate the same or related technical and other engineering programs which are common to several NASA programs and/or different NASA facilities such as Huntsville, Michoud, and Goddard?

ANSWER: Coordination of technical programs at the several field centers is accomplished through the Headquarters Program Offices.

QUESTION: What are NASA's intentions toward assigning fields of responsibility between the Labs and Headquarters? Please differentiate those already assigned in the technologies such as instrumentation, guidance and control, bioscience—human factors, and payloads.

ANSWER: One of the major functions of the Office of Advanced Research and Technology Headquarters staff is to coordinate the inhouse and contracted efforts in research and technology. If in doubt as to which Center has a primary role in certain of these activities, we would suggest calling the appropriate OART technical office or the Office of Program Review and Resources Management for an accurate referral.

QUESTION: Are there any groups presently organized within the NASA organization to study ultimate use of shielding for personnel that may be traveling in space at greater distances than presently achieved?

ANSWER: Yes, Environmental Factors and Technology in the Office of Space Vehicles, Office of Advanced Research and Technology; The Office of Manned Space Flight; and Manned Spacecraft Center.

QUESTION: Would it not be profitable for NASA to have a centralized source of information regarding specific Research and Test facility design?

ANSWER: The Director of Facilities Coordination, Office of Programs, can provide general information on specific facility design and construction projects within NASA or can indicate the specific groups or individuals to be contacted for detailed information.

QUESTION: Where in the NASA organization could we visit to learn more about heavy radar and microwave transmitting equipment? Interest covers design, manufacturing and testing of auxiliary equipment used to shield the transmitter from both RF and X-ray emission.

ANSWER: Mr. N. Heller of the Tracking and Data Systems Division of Goddard Space Flight Center, Greenbelt, Maryland, heads the engineering and operations for the Mercury ground support.

Dr. Eberhardt Rechtin of the Telecommunications Division of the Jet Propulsion Laboratory, Pasadena, California, heads work which includes the use of heavy microwave transmitting equipment in NASA's Deep Space Network.

QUESTION: What group in NASA is concerned with the long range requirements of metallic materials, particularly refractory metals?

ANSWER: The Materials Division, headed by Mr. George C. Deutsch (Code RRM), of the Office of Advanced Research and Technology in NASA Headquarters is responsible for long range requirements in all phases of materials research.

QUESTION: Will the Reliability and Quality Assurance Directors Office be responsible for setting specifications in connection with materials and testing therefor? If not, what group will be responsible?

ANSWER: Responsibility of the Office of Reliability and Quality Asurance in the areas indicated are primarily those of assuring that such specs are developed and used. Responsibility for "setting" particular specifications will be assigned on a case-by-case basis. Particular questions should be referred to the Office of Reliability and Quality Assurance, NASA Headquarters.

LEGAL REGULATIONS

QUESTION: Is NASA contemplating any change in their policy as related to exclusive proprietary design rights regardless of whether these designs are developed under NASA control or company developed and integrated into an NASA design?

ANSWER: While NASA is currently considering revision of its patent waiver policy, it is not presently anticipated that any change other than in the waiver area will be made with respect to exclusive proprietary design rights.

QUESTION: What is the method of submitting and following up vendor developed inventions or improvements to determine depth of interest?

ANSWER: In addition to the unsolicited proposal route, privately owned inventions may be submitted directly to the NASA Inventions and Contributions Board, which may recommend, in appropriate cases, that the Administration grant an award for the contribution of the invention to the aeronautics and space activities of the United States. A patentee wishing to offer a license to the government may submit the offer to the NASA Office of General Counsel, where the degree of interest in the invention will be determined.

QUESTION: Is any change anticipated in the NASA patent policy?

ANSWER: Revision to the patent waiver regulations, proposed in October 1962, is currently under consideration.

QUESTION: Please discuss current patent policy as related to proprietary items in unsolicited proposals.

ANSWER: The submission of a proprietary patentable item as part of an unsolicited proposal in no way affects the rights to the invention itself. Under NASA policy, any properly identified proprietary information in such a proposal will be disclosed only for purposes of proposal evaluation.

QUESTION: What is the latest NASA interpretation on Data Rights?

ANSWER: NASA Data Rights policy is the same as that of the Department of Defense and in essence provides that the government has sufficient rights in information generated under the contract to enable it to reprocure any device developed in performance of the contract.

POLICY

QUESTION: Is NASA going to establish a separate set of cost principles other than Armed Services Procurement Regulation Principles that now govern?

ANSWER: No, NASA is not going to develop a separate set of cost principles.

QUESTION: NASA has established a policy that prorated Independent R & D will not be allowed on development contracts resulting from an unsolicited proposal. Can or will this clause be changed?

ANSWER: Yes, the clause can be changed but whether or not it will be is not certain at the present time.

QUESTION: NASA uses Armed Services Procurement Regulation XV as guidelines for allowable cost. Isn't it consistent that NASA accept Department of Defense negotiated overhead rates?

ANSWER: It is not necessarily consistent that NASA accept Department of Defense negotiated rates until we are organized to participate in such negotiations. Procedures for such participation are currently being explored.

QUESTION: Does NASA plan to implement a program which will facilitate recognition of advance agreements on prorated research and development?

ANSWER: Yes, NASA does plan to implement such a program.

QUESTION: Does NASA follow the policy of encouraging companies to perform Research and Development work on a dollar-sharing basis in order to have a better chance at "follow-on" work?

ANSWER: NASA does not have such a policy. As a matter of practice, however, it frequently happens that NASA will enter into firm-price study contracts and the contractors will, of their own volition, contribute to the study contract.

QUESTION: What steps has NASA taken to avoid duplication of research work on projects which may already have been done on the outside or within other government facilities?

ANSWER: Internal listings (from several sources) of contracting activity regularly are made available to

NASA program managers, as are similar reports supplied by other agencies. The most significant safeguard in avoiding duplication of scientific effort, however, arises from the scientific and technical competence of those in charge of NASA's programs. NASA's program managers are well versed and active in the scientific disciplines associated with their program responsibilities; they are well aware of the state-of-the-art and the areas in which new information is required or of those areas which have been researched excessively. Continuous contact with the scientific literature resulting from NASA projects and with representatives of the scientific and industrial community, supplemented in many instances through their own research efforts, enables NASA staff members to reduce the possibilities of inadvertent duplication of effort to a low level.

PROCUREMENT

QUESTION: So frequently, firm information and early estimates of NASA project requirements are not provided to industry until the time procurement requests are formally released. What, if anything, can be done to provide advanced information officially?

ANSWER: Prior to instituting a procurement action for cryogenic materials, for example, which may result in the construction of new plants, NASA considers the total national production resources and delivery capabilities. The releasing to industry of initial estimates of these materials required to support specific projects or locations could very well portray a distorted picture of the amount to be eventually procured.

QUESTION: What significant differences will there be between the procurement policies and practices of NASA and those of other agencies?

ANSWER: Except in the area of patent policies and procedures, there are no significant differences between NASA's procurement and that of other Government agencies. The principal legal authority for NASA procurements is the same as the military departments, the Armed Services Procurement Act of 1947, as amended, and we work closely with the Department of Defense and the Army, Navy, and Air Force in many respects. To a large extent, Department of Defense contractors will also be NASA's. Our NASA Procurement Regulations are patterned after the Armed Services Procurement Regulation and many of our contract provisions are the same as are found in defense contracts. To the extent possible, NASA also follows Government Services Administration procurement policies and procedures.

QUESTION: NASA Procurement Circular 237, Paragraph 8, is interpreted as requiring the prime contractor to maintain certificates and pricing data on all tiers of subcontractors. Can the Department of Defense defective pricing clause be substituted to serve NASA's purposes?

ANSWER: Public Law 87–653, which became effective December 1962, requires, under certain conditions, that contractors and subcontractors submit cost or pricing data to the Goverment in support of contract negotiations and price adjustments, and that they certify that such data are accurate, complete, and current. The law also provides for reducing the contract price where a certificate has been furnished and the contractor or subcontractor has submitted defective data which have resulted in an inflated contract price.

In implementing the provisions of this law in Circular 257, NASA has placed the responsibility on prime contractors to insure that all cost or pricing data used in support of their contract price are accurate, complete, and current. NASA expects prime contractors to institute and exercise effective controls over subcontractor costs. To assist prime contractors in carrying out this responsibility and to provide NASA contracting officers ready access to all cost and pricing data affecting the contract price, the certificates and pricing data of subcontractors are required by NASA to be submitted to prime contractors and to be incorporated as a part of the prime contractor's records.

The Department of Defense defective pricing clause cannot serve NASA's purpose. This clause is only one of a series of clauses required to be used in Department of Defense contracts. NASA has a single contract clause incorporating all of the features required to implement Public Law 87–653. We feel that our clause is simple, clear, and easy to administer.

QUESTION: Has NASA formulated a policy regarding procurement of simulators and training devices from companies specializing in design, development, and production of such equipment versus obtaining the simulators and trainers from the operational vehicle prime contractor? If so, what is the policy, and if not, is such a policy decision being considered?

ANSWER: NASA has not formulated a specific policy regarding the procurement of simulators and training devices. The determination would be made on an individual case basis whether such devices should be "broken out" or included in the contract of the operational vehicle prime contractor. If "broken out," NASA would buy such devices and make them Government-furnished equipment to the vehicle contractor. If included in the contract of the operational vehicle prime contractor, it is NASA policy to require prime contractors to buy hardware from subcontractors who have a known or developed capability. The prime contractor is not permitted to develop a new capability in competition with available subcontractors who have a known or developed capability.

QUESTION: Does NASA contemplate a "Qualified Products" list such as is used for procurement by other Government agencies?

ANSWER: Not at this time.

QUESTION: How can industry find out the requirements for safety and arming devices, experimental acceleration devices, ground based antennas, communication system and heating fixtures in the ground support equipment?

ANSWER: Since NASA's system of procurement is decentralized, contact should be made with the various field installations to ascertain what procurements NASA is making that may involve items of the types listed in these questions. The pamphlet "Selling to NASA" identifies and locates the various NASA field installations and indicates their fields of interest and effort.

between NASA Headquarters and field installations? How can this service be improved?

ANSWER: By periodic visits to the Industry Assistance Officer, NASA Headquarters, for obtaining information on current procurements and on the program interests of NASA field installations. By making capabilities of the corporation known to responsible NASA officials and by keeping in touch with NASA programs and projects through the records of hearings before the various Congressional committees and through periodic NASA briefing conferences for industry and for technical groups.

QUESTION: What, specifically, is NASA doing, or attempting to do, that will help protect interests of smaller—but technically dependent—organizations that usually find themselves at the second, third, and sometimes even fourth subcontract tier? What can these companies do to protect their own interests?

ANSWER: Various NASA procedures offer assistance to smaller companies in obtaining NASA business at the prime or subcontract level. Thus, to assist at the prime contract level:

1. NASA promptly publicizes proposed advertised or negotiated procurements to be made in the United States, which may result in an award in excess of $10,000, in the Department of Commerce publication, "Commerce Business Daily."

2. Through the booklet, "Selling to NASA", NASA identifies and locates the various NASA field installations and indicates their fields of interest and effort so that prospective contractors can file a Standard Form 129 (Bidders' List Mailing Application) at those installations most likely to issue bids or proposals for which the company would consider itself qualified.

To assist at the subcontract level:

1. NASA synopsizes all unclassified research and development procurements, which may result in awards of $100,000 or more, in the Department of Commerce "Business Daily" simultaneously with the mailing of requests for proposals to prospective offerors. In addition to furnishing a description of the proposed procurement, the synopsis contains a list of the companies, with their addresses, invited to submit proposals. This procedure offers concerns interested in subcontracting the opportunity to contact prospective offerors at the time they are preparing their proposals for prime contract awards.

2. NASA includes a clause, entitled "Small Business Subcontracting Program", in all contracts which may exceed $500,000 and which, in the opinion of the contracting officer, offer substantial subcontracting possibilities. Under this clause, the contractor assumes specific responsibilities designed to insure that small business concerns are considered fairly in the subcontracting role and to impose similar responsibilities on major subcontractors. The contractor maintains certain records on his subcontracting, and submits periodic reports to NASA Headquarters on subcontract awards to small business concerns.

QUESTION: How are negotiated contracts obtained? Are such contracts restricted to classified projects and are conferences planned for such projects?

ANSWER: A booklet entitled "Selling to NASA" indicates the procedures for bidding and quoting on NASA procurements. This booklet may be obtained from the Industry Assistance Officer, NASA Headquarters or from one of the field installations. Negotiated contracts are awarded on both classified and unclassified projects. The need for a preproposal conference depends upon the complexity of the procurement and not on the security classification.

QUESTION: What is the program for small business on microelectronics?

ANSWER: The small business program is general in its application. Firms in the field of microelectronics may take advantage of the methods employed by NASA in its efforts to assist small business primarily at the subcontract level. Additional information on NASA's efforts to assist small business are set forth in page 15 of the booklet.

QUESTION: What criteria determines NASA's choice of the type of contract to be used?

ANSWER: The firm fixed-price contract is the preferred type of contract and NASA uses it whenever practicable. This type of contract is best suited for procurements where reasonable definite specifications are available, price competition exists, production experience is present, and costs can be predicted with reasonable certainty. NASA finds its largest use for this type of contract in formally advertised procurements and in small purchases ($2,500 or less). NASA also uses this type of contract for other negotiated procurements whenever specifications are definite enough to permit the solicitation of proposals on a price basis. The cost-plus-fixed-fee contract finds ready use in situations where definite specifications are not available and costs of performance cannot be estimated with any reasonable degree of accuracy. It is used extensively by NASA in the procurement of research and devolpment where the lack of definite specifications and the absence of cost experience data are common conditions. Since the cost-plus-fixed-fee contract offers the contractor little incentive to reduce costs, NASA is directing increasing attention and effort to the inclusion of incentive provision in contracts. NASA uses the usual incentive type of contract, which establishes a target cost and sharing arrangement or formula under which the contractor participates with the Government in savings below the target cost and in costs above the target cost, whenever cost experience data are available on which a realistic target cost can be based. NASA is trying a performance type of incentive contract known as a cost-plus-award-fee contract. This is a cost-reimbursement type of contract under which the basic fixed fee is subject to upward adjustment by a maximum amount on the basis of a unilateral evaluation by a senior NASA official or board, specifically designated in the contract, of the contractor's performance under the contract. The general criteria that will be used in evaluating the contractor's performance are set forth in the contract.

QUESTION: What is the role of small business within NASA at the present time, and what is its contemplated role for the future?

ANSWER: Small business has a substantial role within NASA. During fiscal year 1962 NASA placed approximately $123 million of its contracts with small business firms. This is $58 million or 89 percent more than in

CONTRACTS

QUESTION: The procurement of test equipment is likely to be a low echelon of contractor supply—is there any way in which the space program can be helped by a company briefing NASA staff on the state of the vibration test equipment for structural evaluation or reliability specification?

ANSWER: Although the acquisition of special test equipment is generally accomplished by the prime contractor for NASA, information involving state of the art equipments should be made available to the NASA project manager in order that review and evaluation of these equipments with the contractor may precede such acquisition. Vibration test equipment to determine structural reliability is one type which warrants maximum consideration prior to selection. NASA project management staffs would be helped by industry briefings on such equipments.

QUESTION: Can it be expected in the future that NASA will secure and accept the audit of contractors by existing cognizant military agencies, rather than duplicate this function at NASA?

ANSWER: Fullest utilization is made of military audit capabilities. We have, in fact, a program of coordination with military auditors which is directed toward securing the type, quantity, and quality of information we desire from them in lieu of supplementing their efforts by our own.

QUESTION: Where is the decision level on the choice of subcontractor for the various subsystems made?

ANSWER: Subcontractors are selected by the prime contractors and deal directly with them rather than with the Government. This is so because of the lack of privity of contract between the Government and subcontractors. NASA's influence as to subcontractor choice is through:

(1) Approval by the contracting officer of contractors' "make-or-buy" programs;
(2) Contracting Officer's approval of certain subcontracts under the subcontract approval clause of the contract;
(3) Headquarters review of subcontracts of $5,000,000 or more prior to approval by the contracting officer.

QUESTION: What criteria, in addition to contract value, governs approval of CPFF subcontracts from Prime Contractors for development hardware?

ANSWER: A CPFF subcontract under a prime contract, containing a "Subcontracts" clause providing for Government consent to subcontracts, would require such Government consent regardless of the dollar amount. In reviewing the subcontract, a most important determination made is whether the CPFF type of subcontract is the proper type—that is, whether the uncertainties involved in subcontract performance are of such magnitude that the cost of performance cannot be estimated with sufficient reasonableness to permit use of a fixed-price type of subcontract. In addition, the subcontractor's cost accounting system must be adequate for the determination of costs applicable to the subcontract, and the Government must be satisfied that there is adequate provision for appropriate surveillance by prime contractor and/or Government personnel during performance to give reasonable assurance that inefficient or wasteful methods are not being used. The reasonableness of the estimated subcontract cost is appraised on the basis of the currency and completeness of the costing data. Also, if the use of CPFF subcontracts is repetitive or unduly protracted, such use will be looked on with skepticism by contracting officers.

QUESTION: Does NASA predict an increase or decrease in preference for CPFF contracts, as opposed to other types, for development contracts?

ANSWER: NASA predicts a decrease in preference for CPFF contracts. Increased effort and attention are being directed to the use of contracts with incentive provisions in lieu of CPFF contracts.

QUESTION: Under what conditions, and to what level of sub-tier subcontractors, will PERT reporting requirements be applicable?

ANSWER: NASA does not specify PERT reporting below the prime contractor level. Prime contractors are encouraged to develop reporting systems with their subcontractors that can yield data compatibility with NASA's PERT reporting requirements.

UNSOLICITED PROPOSALS

QUESTION: Where should unsolicited proposals for basic or applied research be submitted?

ANSWER: All unsolicited proposals should be addressed to the National Aeronautics and Space Administration, Washington 25, D.C., marked: Attention: Office of Grants and Research Contracts. Fifteen copies should be submitted. These proposals are studied by a special staff. Proposals which would further NASA programs and not duplicate existing work to an unreasonable degree are then referred to NASA engineers and scientists in Washington and in the field who make individual reports and recommendations to the appropriate NASA officials. Constant effort is made to speed up the reviewing process.

QUESTION: What is the procedure when industry has a project in mind that they would like NASA to sponsor for the mutual benefit of both?

ANSWER: If the contemplated project is of a research nature, either basic or applied, it may be brought to NASA's attention via the mechanism of the unsolicited proposal. Prior contact with NASA technical personnel will often reveal the existence or lack of a community of interest; if such a mutual interest exists the submission of an unsolicited proposal is advisable. Further information on the procedures to follow may be found in the Office of Grants and Research Contracts Brochure, copies of which are available, upon request, from the Office of Grants and Research Contracts. Where an industrial organization is interested in highly developmental work or in selling "off-the-shelf" items, contact should be made through the appropriate Agency Procurement Office, as described in "Selling to NASA".

INDUSTRY-GOVERNMENT RELATIONS

QUESTION: In what way can a Washington, D.C., representative of a nationwide corporation provide liaison fiscal year 1961. Twenty-four of the one hundred contractors receiving the largest dollar value of NASA's direct awards to business during fiscal year 1962 are small business. Small business set-asides totaled $14 million during this period, or 133 percent more than in fiscal year 1961. NASA will continue to exercise its efforts to place a fair portion of its purchases and contracts with small business and to afford small business an equitable opportunity to compete for contract awards at the prime contract and subcontract level.

QUESTION: Scientific programs proposed by universities are usually carried out in cooperation with an industrial firm to supply engineering manufacturing functions. Does NASA publish anywhere experiments they approve for the coming year, etc.?

ANSWER: NASA releases monthly notices of contract and grant awards in excess of $50,000. While there is no public release for projects under $50,000, it is unlikely that these smaller tasks would afford much potential as a source of subcontracts.

These monthly releases are given wide distribution, including:

Washington Press Corps
Major Metropolitan daily newspapers
Some smaller newspapers
Major radio and TV stations
Trade magazines
Trade newspapers

The actual use of this material is, of course, at the discretion of the publisher. Information selected from the news releases typically appear in:

"The Space Letter"
"Space Business Daily"
"Space/Aeronautics"
"Aviation Daily"
"R & D: The Research and Development Weekly"
"Commerce Business Daily"

Further information may also be obtained through such private organizations as the Commerce Clearing House (Washington, D.C.). As this information is made widely available, industrial organizations might be advised to apply a litle "reader pressure" if their favorite trade journals are not publishing all the news that fits.

A list of recently approved studies was made available at the National Aeronautics and Space Administration-Industry Conference and can be obtained from NASA Headquarters, Code AFC.

GOVERNMENT-OWNED EQUIPMENT

QUESTION: Is it NASA policy to encourage the use of machinery and equipment which is in government storage, or do you prefer contractor investment in facilities of this type?

ANSWER: It is NASA's policy that contractors furnish all equipments for missions. NASA reserves the right, however, to furnish equipments available from Government storage where it is considered to be in the best interest of the Government to do so. NASA PR 13.102-3 *Facilities* sets forth the policy in this respect.

QUESTION: What percentage of equipment in missions is Government furnished? Is prime contractor furnished?

ANSWER: NASA spends over 90 percent of its budget on industrial contracts. Only a small percentage of the mission equipment is developed in-house.

However, NASA contracts separately with associate contractors for certain items of mission equipment that are furnished to the prime contractor. For example, the following equipment is being developed for NASA by associate contractors to be furnished to North American Aviation Company, the prime contractor for the Apollo Command and Service Modules:

Pressure suit
Research and development instrumentation
Guidance and Navagation System
Propellants
Scientific instrumentation
Crew personal equipment

QUESTION: Could NASA clarify its policy with respect to Government-Owned-Contractor-Operated versus Contractor-Owned-Contractor-Operated plants for producing propellants?

ANSWER: NASA policy has been to utilize existing production capacity of both Government-owned and contractor-owned plants. When new production capacity has been required, NASA has contracted commercially for product to be supplied from contractor-owned plants.

MILITARY COORDINATION

QUESTION: Does the office for coordination of programs with the military service provide for coordination in the area of long-range planning?

ANSWER: NASA has a Deputy Associate Administrator for Defense Affairs, whose function is the coordination of NASA and DOD interests. He is a member of the Aeronautics and Astronautics Coordinating Board and of the Gemini Program Planning Board. Both of these groups address themselves to the coordination of present and future programs of mutual interest to NASA and the Department of Defense.

The Defense Affairs Office, in fulfilling its program coordination function, assists in establishing and monitoring relationships between NASA and DOD program offices. These relationships are set up to deal with both current and future programs.

FILM PRODUCTION

QUESTION: Does NASA include in its program film productions that could be planned well in advance and possibly included in the planning of its suppliers for the coming year, or will the production be assigned as in the past, as the need occurs?

ANSWER: Film Progress Reports, produced as part of the R&D contract, are planned by each program office in the Centers. However, information and education film productions contracts are normally placed as a result of competitive bidding. Most of these film requirements are synopsized and published in the Department of Commerce "Daily Journal" and any company wishing to submit a proposal may do so. NASA normally receives between 25 and 50 proposals on each requirement. None of these proposers has ever indicated any difficulty in scheduling production if awarded an NASA contract. Headquarters plans its production program well in advance of each fiscal year. In the early stages, the subjects named for possible production are tentative and subjected to intensive study. Occasionally, these initial plans are deferred. Additionally, new requirements are sometimes generated which were not previously anticipated. Consequently, the priority of a subject may change from initial to final planning. Film production in this category is set aside for small business.

ENGINEERING SERVICES

QUESTION: What are the opportunities for rendering engineering-architectural services to NASA?

ANSWER: The records of the hearings before the various Congressional committees describe all items for which funds are budgeted. In addition, the Industry Assistance Officer can give some assistance which may reduce the need to visit each Center. However, the selection of the Architect-Engineer is the responsibility of each Center, and Standard Form 251 (U.S. Government Architect-Engineer Questionnaire) should be filed with each Center.

QUESTION: What is NASA procurement policy in all locations in the field of reproduction and printing services and various engineering supplies?

ANSWER: NASA's policy on the procurement of printing is based on strict adherence to 44 U.S.C. and "Government Printing and Binding Regulations" published by the Joint Committee on Printing, Congress of the United States. All printing for common use by NASA installations, not including contractors, is ordered by Headquarters from the Government Printing Office. Such printing is procured from commercial sources by competitive bids, only if the Public Printer issues a waiver, usually on the basis of inability to meet a deadline or of "one source of supply." Printing requirements peculiar to a field installation are met by in-house printing facilities (if such exist), by other Government printing facilities, or by commercial sources on competitive bids. In-house facilities are used only for short-run, small-volume, close-deadline printing which cannot be obtained from commercial sources. Each installation manages its own printing procurement program. Procurement officers are the appropriate ones to contact regarding current procurements. Printing required by contractors or grantees *for their own use* in responding to their contract or grant is entirely within their province and NASA has no jurisdictional interest therein. As regards "various engineering supplies", NASA procures such supplies by formal advertising when specifications are firm enough to solicit bids and make award to the lowest responsible bidder whose bid is responsive. Otherwise, such supplies would be procured by negotiation with sources considered qualified.

QUESTION: What programs and which NASA field installations will the Corps of Engineers (or Bureau of Yards & Docks or other Federal agencies) have the contractual responsibility of the construction and related engineer services?

ANSWER: Much of the construction work at Cape Canaveral, Huntsville, the Mississippi Test Site, and the Manned Spacecraft Center at Houston, Texas, is being accomplished for NASA by the Corps of Engineers. By agreement, the services of the Bureau of Yards & Docks, Department of the Navy, may be utilized for such projects as down-range sites for Atlantic Missile Range, Pacific Missile Range and elsewhere, as desired by NASA.

NASA field installations should be contacted for information on construction projects being handled for NASA by other Government agencies.

QUESTION: What are NASA's future plans in regard to the cement and concrete requirements for Launching Pads and associated facilities?

ANSWER: Contact should be made with the procurement offices of the field installations that are undertaking construction projects of the types indicated in the question (such as, Marshall, Manned Spacecraft Center, and Launch Operations Center). The necessary details are set forth in the booklet "Selling to NASA".

QUESTION: Could NASA project for the next three years the amount of money to be spent on construction at each NASA installation?

ANSWER: The level of construction at NASA installations in future years will depend upon specific program recommendations by the Executive Department and approval by Congress. A projection of dollar volumes is, therefore, not possible.

QUESTION: An engineering contracting firm is awarded a study contract for an NASA project or facility or component—then is invited to tender on the design—and is retained by NASA to prepare the design and specification. Does this then eliminate this firm from tendering on the construction contract?

ANSWER: The answer is generally yes. It is NASA's policy that the award of a contract for architect-engineer services for a particular facility and the award of a contract for the related construction work to the same firm, its subsidiaries, or affiliates, is prohibited. This policy prevents the development of situations where architect-engineer firms might be discouraged from furnishing their best professional services and from rendering unbiased decisions during the design and construction periods. This policy is not applicable to (1) those cases where the Director, Procurement and Supply Division, NASA Headquarters, specifically authorizes, prior to the initiation of negotiations, the use of a cost-plus-a-fixed-fee contract for both the design and construction of a specialized facility; or (2) those cases where a contract is awarded on the basis of performance specifications for the construction of a facility, and the contract requires the contractor to furnish construction drawings, specifications, or site adaptation drawings of the facility.

ROCKETS

QUESTION: Do NASA plans for the conduct of future programs in the sounding rocket and reentry test vehicle area envision extensive use of obsolescent military rockets such as Jupiter and Thor, or are there plans for new procurements? If so, what can you say about these new plans?

ANSWER: The meteorological sounding rocket program has no plans to use rockets as large as the Jupiter and Thor. This program will use rockets of the Nike-Cajun type, and the Arcas and Loki types, all of which have been in extensive use during the last few years.

QUESTION: How does the 260-inch diameter solid rocket booster fit into NASA programs? What NASA funds are budgeted for this booster? Are DOD funds budgeted for this booster also?

ANSWER: NASA has requested the Department of Defense to undertake a development of a very large solid rocket booster to provide a technical base for future planning of very large launch vehicles. All funding of this development will be carried out by the Department of Defense. NASA will not be funding the basic developments.

QUESTION: What is NASA's position with regard to the 156-inch-diameter solid propellant boosters for large launch vehicles?

ANSWER: The 156-inch-diameter solid propellant motor size is not being seriously considered by NASA for large launch vehicles. The primary interest in NASA is directed toward the 260-inch-diameter motor.

QUESTION: Please comment on the need for the Nova Launch Vehicle program in view of its probable cancellation due to the success of Gemini and Apollo.

ANSWER: The need for the Nova size launch vehicle has been placed far enough in the future that the possibilities for advanced non-V-2-like designs are increased.

QUESTION: Does NASA have firm plans for a space launch vehicle between Scout and Titan III launch capabilities?

ANSWER: The only vehicle in this range which NASA has under development is the well known Centaur vehicle.

MANNED SPACE FLIGHT

QUESTION: What are the present long-range plans for manned missions and the expected ratio of Government to contract-furnished equipment?

ANSWER: Regarding the status of long-range planning for manned missions in general, a simple answer is that both the Office of Manned Space Flight and the Office of Advanced Research and Technology are looking at the possibilities of the future as being composed of three major areas. These are manned orbiting space laboratories; advanced lunar bases; and manned planetary expeditions. As noted at the Industry Conference, there have been several contracts for studies concerning these missions let to industry. Because of the early status of the studies, it is impossible to comment on the ratio of Government to contractor furnished equipment for such further missions.

QUESTION: How is NASA controlling the Gemini program?

ANSWER: Overall direction of Project Gemini is exercised by NASA's Office of Manned Space Flight and the Manned Space Flight Management Council. The Management Council is comprised of the key officials in the Office of Manned Space Flight and NASA's Manned Spacecraft Center, Marshall Space Flight Center, and Launch Operations Center. The day-to-day management responsibility for the Gemini development effort rests with NASA's Manned Spacecraft Center, specifically, the Gemini Project Office, headed by Mr. James Chamberlin. The direct management of the contractor development effort is accomplished by the Manned Spacecraft Center. The NASA team is supported by the Department of Defense in the areas of launch vehicles development and procurement, launch operations and recovery. This support is coordinated by the Manned Spacecraft Center.

QUESTION: What is the timing for the initiation of a program for the lunar logistics system and the lunar roving vehicle payload?

ANSWER: The National Aeronautics and Space Administration sponsored study effort to define possible Lunar Logistic Systems, as well as our analysis of these studies to determine the need for such a system, is essentially complete. A decision on required new development effort (if any), as well as on the timing for initiating such development, should be forthcoming within a few months.

QUESTION: Please comment on the sequence and interrelationship of the following systems:

a. Lunar Reconnaissance Module (manned). A film record to be returned to earth in the Command Section. Operational in 1965, but would require use of the Saturn booster which isn't operational.

b. LEM. Uses information from other vehicles to determine right landing area. Operational 1967 to 1970.

ANSWER: Informal studies of manned reconnaissance from lunar orbit using the Command and Service Modules have been underway. No conclusions from these preliminary studies have been made at the present time. The Lunar Excursion Module will not land on the lunar surface until certain data in the area of the landing site are available. These data may be obtained by manned reconnaissance from lunar orbit, from the Ranger and Surveyor programs, or by the combination of data from those programs together with final check during the hover phase of the LEM landing.

QUESTION: What types of power sources are being considered for the various types of space vehicles now on the drawing board? This would include both manned and unmanned vehicles designed for "short range" and deep space work.

ANSWER: Space power energy sources being considered for various types of space vehicles now on the drawing board consist of the following:

a. Chemical sources
b. Solar sources
c. Nuclear power

Selection of a particular system depends upon the required power level and total electrical energy to be consumed on a mission. The first category, chemical sources, includes batteries, fuel cells, and chemical engines. The second category, solar sources, includes solar cells, thermionic power systems combined with mirror concentrators, and solar dynamic systems.

With respect to nuclear electric power systems, NASA is presently performing detailed studies dealing with the use of radioisotope power for communication satellites, weather satellites, payload power for space probes, and so forth. Requirements have been established at present for the Interplanetary Monitor Probe (IMP) and Project Surveyor. Isotope power is limited by weight and size considerations to maximum power levels of the order of hundreds of watts. With regard to fission reactor systems, NASA is developing the Snap-8 Rankine cycle system which will develop a power of 35 kilowatts with possible extension to approximately 60 electrical kilowatts. A technology program is proceeding which will lead to the eventual development of much lighter weight systems with power levels of at least a megawatt and operating lifetime of over a year.

QUESTION: What is the status of the program for the development of a manned erectable orbiting space platform?

ANSWER: Our work in FY 1963 will be devoted to paper studies on the two principal types of orbiting space stations. One will be studies on a large erectable station requiring launch by a Saturn V, and the other will be studies on configurations requiring launch by Titan II or Saturn I class vehicles. These studies are designed to evaluate the trade-offs between possible configurations; they will also provide the preliminary information required for evaluation of possible programs in this area.

UNMANNED SATELLITES

QUESTION: What are the future plans for the "Anna" geodetic satellite program?

ANSWER: Project Anna has been transferred from the Department of Defense to NASA. NASA is now definitizing a detailed Project Development Plan for conduct of the geodetic satellite program.

ADVANCED RESEARCH

QUESTION: What information can our organization obtain which will tell us of other groups working on similar work under contract to NASA?

ANSWER: Organizations can obtain a description of all proposed procurements and a list of companies (with addresses) which will be solicited for proposals from the NASA synopsis in the Department of Commerce "Business Daily. Another potential source of information as to other groups contracting with NASA is the NASA field centers contracting in the area of research and/or development in which the organizations are interested.

QUESTION: What is the method of setting the level of the budget for Advanced Research and Technology? Is it a percentage of the total NASA budget?

ANSWER: This budget is set the same way as that of other Headquarters offices; it is not a fixed percentage of the total NASA budget. The proposed program of the Office of Advanced Research and Technology, with justification for increases and decreases, is submitted and subsequently discussed with the Associate Administrator and his staff at which time a budgetary level is agreed upon.

QUESTION: NASA sponsors development of what type of materials? In addition, what kind of materials offers improved performance for future application?

ANSWER: NASA is currently sponsoring research in all fields of materials to support engineering developments. These materials include polymers, ceramics, composites, lubricants, and refractory metals. The materials research encompasses all environmental factors applicable to space including extreme temperatures (hot and cold), hard vacuum, micrometeoroids, and electromagnetic radiation.

QUESTION: What plans does NASA have for conducting experimental programs for testing in a space environment, promising components and novel equipments which are not directly associated with a planned NASA operational program?

ANSWER: The Office of Advanced Research and Technology is the office which has primary responsibility for work leading to the feasibility of concepts, techniques, and "breadboard" hardware having general application to NASA's missions. This, however, does not preclude the other offices from pursuing some developments for which a definite improvement in an R&D system can be foreseen.

QUESTION: How might a company attain development programs for elastomeric materials?

ANSWER: Programs in both basic research and applications for elastomers are sponsored by NASA Centers and Headquarters offices. If the proposed work is in the nature of research and development, not applied to a specific program, the Space Vehicle Structures Group or the Materials Group of the Office of Advanced Research and Technology at NASA Headquarters may be contacted for information.

QUESTION: What are the support requirements for V/STOL or rotary wing aircraft?

ANSWER: It is assumed that "support requirements" refers to operational needs of terminals and landing sites; vehicle-spare part support; mechanic and other personnel requirements; etc. Some NASA views on take-off and landing facility needs are included in NASA TN D-624, "A Preliminary Study of V/STOL Transport Aircraft and Bibliography of NASA Research in the VTOL-STOL Field". No other NASA studies in these areas have been conducted. A copy of the publication can be obtained by writing to Office of Technical Services, Department of Commerce, Washington 25, D.C. ($2.75 per copy).

QUESTION: To what extent will the pumping of liquid metals be employed in space projects? Which of the liquid metals seems most favorable?

ANSWER: Liquid metals are used in the space power program for two principal purposes, (1) as a very efficient heat transfer coolant, and (2) as a working fluid for high temperature applications where conventional fluids such as steam would have excessive vapor pressure. The liquid metals are used primarily in nuclear electric power systems, but are also used in solar mechanical power systems.

There are two liquid metal systems presently under development by NASA: (1) the 30-kilowatt Snap–8 system which uses a mixture of sodium and potassium as a reactor coolant and mercury as the liquid to be the vaporized working fluid, and (2) the 3-kilowatt Sunflower solar electric power system which uses mercury again as the fluid which drives the turbine-alternator unit. Both systems require pumps, either mechanical or electromagnetic, for circulation of the energy conversion and reactor liquids.

Technology work is also being performed in nuclear power systems which are required to be much lighter in weight and to operate for longer times and at higher power levels than Snap-8. Such systems cannot be defined in detail at this time due to space environment uncertainties and other factors. However, it is probable that they would use either lithium, sodium, or potassium as reactor coolants, and either potassium, cesium, or sodium as working fluid. Another advanced system concept of interest is a system utilizing thermionic direct conversion. At higher power levels, this system also would require a pumped liquid metal coolant for removing cycle waste heat.

The actual requirements for liquid metal pumping equipment will depend to a great extent upon the technological progress which is made on the programs mentioned.

QUESTION: Will advanced research and technology programs be cut back as a result of funding needs for Apollo?

ANSWER: No. Advanced research and technology programs may never be as large as some would like. The size of the program will be based on what NASA believes it must invest to insure a proper basis for future R&D programs. The support of any NASA program must be kept in balance and within the overall funding provided by the Congress.

QUESTION: Are there any firm, irrevocable plans in NASA to provide a sound base in advanced technology on which our future space efforts can be based?

ANSWER: NASA has every intention of continuing its in-house competence in advanced technology and, in fact, is building more competence in this area through contracts with universities, nonprofit institutions, and industry.

QUESTION: What are the more promising concepts for earth-to-earth orbit transportation?

ANSWER: It would appear at this time that NASA will make maximum utilization of both Gemini and Apollo configurations for earth-to-earth orbit transportation, for some time in the future. It is true that as the requirements for such transportation increase, these systems will become too small to be economical. There are several studies underway at the present time to examine the vehicle requirements for larger payloads, and these, in general, center around the so-called "lifting body vehicle" capable of carrying 12 or more passengers. Such vehicles could be boosted by Saturn V type launch vehicles. NASA has also studied launch vehicle configurations designed to take off and land as aircraft, and which would be capable of earth-to-earth orbit transportation.

QUESTION: What are NASA-expected expenditures regarding boosters, manned and unmanned space flight, navigation, guidance and control through 1972?

ANSWER: The appropriations for FY 1964 are subject to Congressional action on the President's FY 1964 budget request, and appropriation levels beyond FY 1964 are subject to both future Executive Branch recommendation and Congressional action. Hence, it is not possible to make a meaningful projection of NASA expenditures to 1972, either in total or for the subdivisions indicated.

QUESTION: What are the requirements for electronics and control equipment, and how can companies learn of these requirements in an economical way?

ANSWER: The requirements for electronics and control equipment are many and varied to meet specific launch vehicle, spacecraft, and tracking system requirements. Companies interested should contact the appropriate Centers or the Program Offices at Headquarters directly, including the Analysis and Requirements Division, Electronics and Control Directorate, Office of Advanced Research and Technology, to discuss areas in which they might be interested in participating.

To consider one area, Meteorological Systems is interested in the development of the following new or improved instrumentation for flight systems. All or part of it may be considered electronic:

a. A nighttime cloud photography system (image orthicon camera).

b. A dielectric (or electrostatic) tape system development (camera).

c. Radar type and sferic sensors to make atmospheric measurements.

d. Improved spectometric apparatus.

e. Improved (more efficient, smaller size) power supplies for satellite environment.

f. Improved power, recording, command, and control systems, and stabilization techniques.

g. Improved reliability in all air-borne electronic packages, including telemetry, analog-to-digital conversion equipments, and transmitters.

h. More precise and accurate sensors for measuring the visible and infrared spectrum.

DATA PROCESSING

QUESTION: In the publication "Electronic News", it is stated that "what is needed is intelligent data processing". What specific projects are of immediate concern? What is the avenue for demonstrating the value of theoretically feasible information compressing instrumentation and data processing methods?

ANSWER: It is not known specifically what the author had in mind when stating that "what is needed is intelligent data processing," but one certainly cannot disagree. In general, satellites of the large scientific type (requiring Atlas boosters) generate the greatest data processing workload. Project managers for large scientific satellites, such as the orbiting observatories, are located at the Goddard Space Flight Center in Greenbelt, Maryland. Contact with the appropriate manager would be necessary to determine whether any requirements exist for the proposed instrumentation and data processing methods.

U.S. GOVERNMENT PRINTING OFFICE: 1963 O—677877